ELECTRICAL ENGINEERING

FEBRUARY 1951

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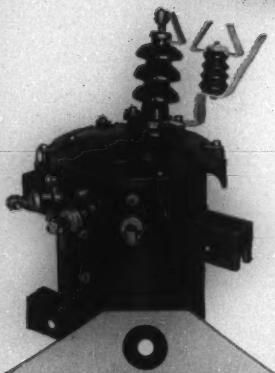

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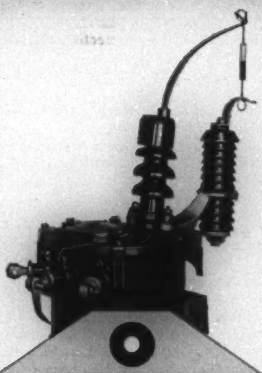

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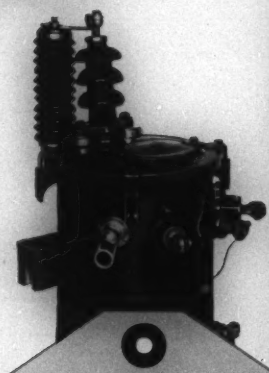

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FEBRUARY

1951

The Cover: The new Ridgeland Station of the Commonwealth Edison Company of Chicago, Ill., is shown. The first 150,000-kw unit was placed in service October 29, 1950; the second 150,000-kw unit now is under construction and will be in service in 1951; two more units are to be built and service is scheduled for 1953. An ultimate capacity of 600,000 kw is planned (see story on page 106). Commonwealth Edison Company photo

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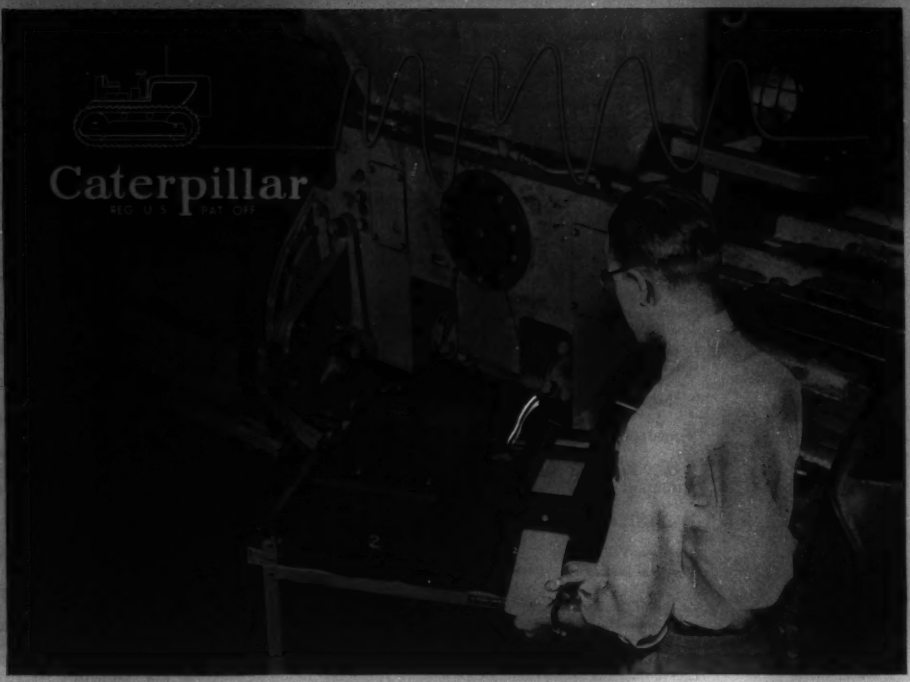

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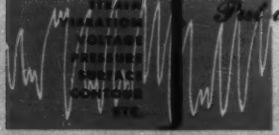

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HIGHLIGHTS.....

Continuing Technical Leadership. Our country needs technically trained young men, yet by 1954 there will be only 15,000 engineering graduates, says AIEE President LeClair. We cannot afford even for a single year to stop the flow of young men from high school into engineering training (*pages 95–96*).

The Critical Shortage of Engineers. The minimum annual need of engineering graduates is 30,000, says S. C. Hollister, Dean, College of Engineering, Cornell University. How do we obtain this number when there are not enough freshmen enrolled and when those in college are subject to the draft? The situation is very serious, and Dean Hollister discusses many aspects of the problem (*pages 97–99*).

Electrical Safety in Laboratories. In order to make engineers more aware of hazards inherent in laboratory work, a discussion of these hazards is presented this month. Suggestions are made to make laboratory equipment safer and to educate laboratory workers to be conscious of the care which must be exercised (*pages 99–103*).

Principles of Professional Conduct. The Statement of Principles of Professional Conduct of the AIEE gives the canons of ethics for engineers, the code of business practice, the use of membership designations and Institute insignia, and the history of the canons and code (*pages 171–73*).

Chicago's New Ridgeland Station. Placed in service October 29, 1950, was the first of four 150,000-kw generating units of the Ridgeland Station of the Commonwealth Edison Company. Work was started on this station in August 1947, and the plant is scheduled to reach its ultimate capacity in 1953 (*pages 106–10*).

Obtaining Registration As a Professional Engineer. This article reviews registration laws and requirements and the advantages to the engineer of being registered. The author also includes a list of national registration boards and boards of examiners (*pages 113–15*).

Test of 220-Kv Circuit Breakers. By modifying equipment and circuits of a 220-kv line, tests have been made in Sweden to obtain data which may be applied to the new 380-kv transmission system. The tests were carried out to investigate the interruption of line-charging current by means of high-speed air-blast circuit breakers (*pages 118–24*).

Information Theory Applied to System Design. The information theory as it may be applied to the design of a communication system is discussed this month by W. G. Tuller of Melpar, Inc. By the use of the information theory in this type of analysis, the effect of necessary deviations from the ideal in bandwidth, power, and speed may be evaluated (*pages 124–26*).

Local Wire Television Networks. Newly developed low-loss shielded video cable pairs have been used to form a local video distribution system. It provides equalization for the cable loss, amplification of the signal, and suppression of high-frequency noise (*pages 130–35*).

Ice Testing of Outdoor Switches. The testing of an outdoor switch under artificial icing conditions is presented by J. B. Owens of the Westinghouse Electric Corporation. Design features of a switch which can be operated under such conditions are described (*pages 139–42*).

A Simple Magnetic Modulator. The design of a magnetic modulator to furnish a constant-phase a-c signal from a d-c signal which does not go over 100 millivolts at 1,000 ohms is discussed. To obtain a sinusoidal signal the equipment had to be designed to operate over a small part of the magnetization curve (*pages 144–47*).

Insulation Resistance on Energized Systems. The insulation of electric systems of ships tends to deteriorate rapidly, and it is desirable to measure the resistance of the system quickly and accurately without de-energizing the system. In order to do this with a single reading, a new instrument has been developed for use on either d-c or a-c systems (*pages 150–54*).

Totally Enclosed Motors. A study of the use of totally enclosed auxiliary drive motors has been made by engineers of the Consolidated Edison Company of New York, Inc., to determine the performance and cost of operation of these machines. The use of this type of motor has cut down outages considerably, and maintenance cost has been reduced (*pages 155–59*).

1950 Engineering Developments. In the section on Insulated Conductors (*EE, Jan '51, pp 6–7*) the conductor size of the 69-kv oil-filled segment cable, shown on page 7, should be 2,750,000 circular mils. The last sentence of the paragraph under the photograph should have referred to the conventional concentric stranded type of hollow core oil-filled cable instead of the pipe type of construction.

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AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Feb '50, p 46A	Winter General
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General
Nov '50, p 43A	Middle Eastern District Fall General

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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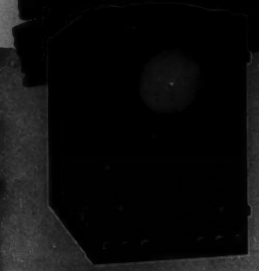

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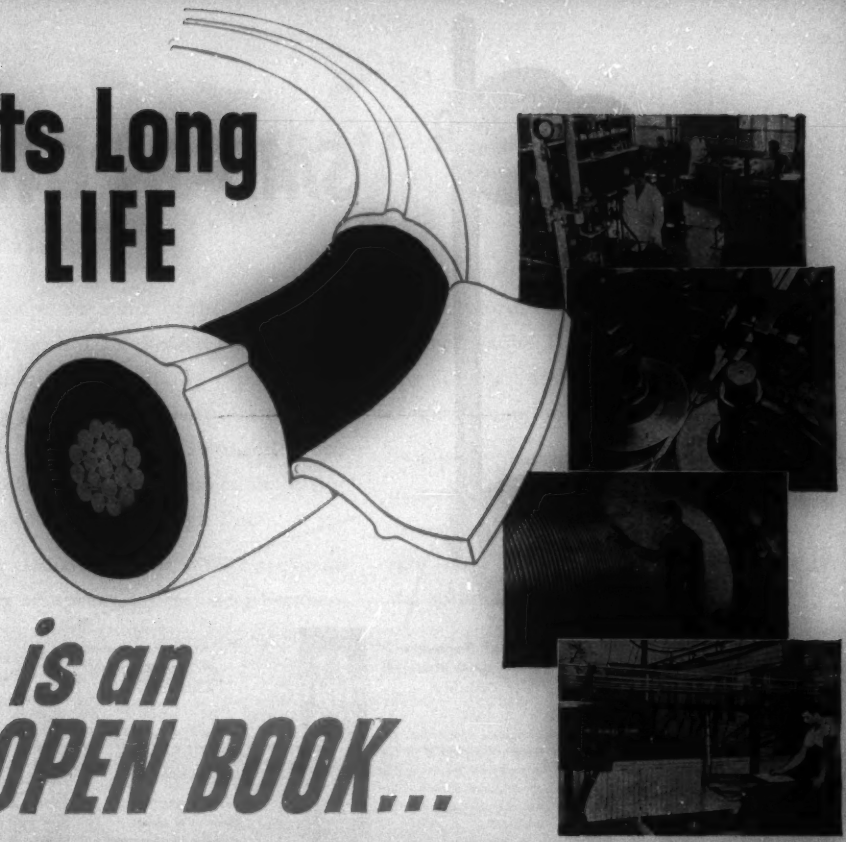

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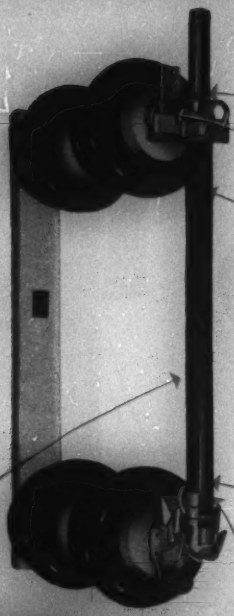

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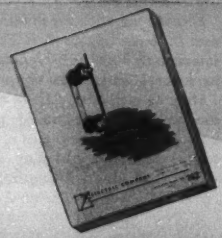
a choice of time-current characteristics to provide flexibility in coordinating with other primary, and with the secondary, protective devices.



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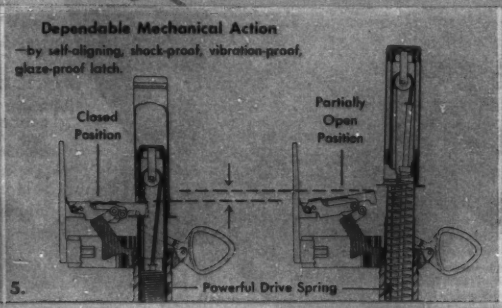

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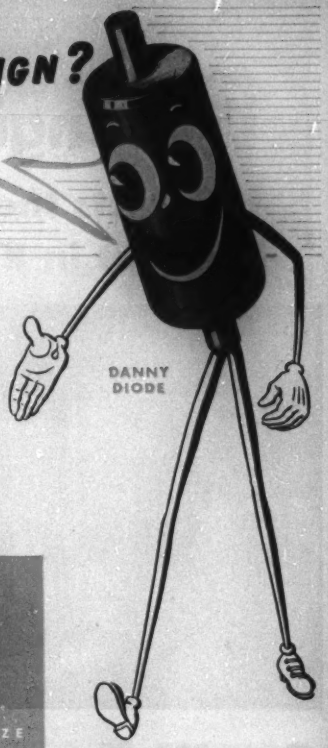

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*formerly designated G-7

SPECIFICATIONS

UHF TYPE 1N72 (Formerly Designated G-7)

Specifications at 25° C:

Design frequency.....500 mc
Useful frequency range.....DC to over 1,000 mc
Noise figure.....14 to 19 db*

*Measurements made with Measurements Corp. Model 84 Signal Generator, R.C.A. Model A Converter with 0.7 ma rectified local oscillator current and G-E Model 814 television receiver with television channel 3 used as IF frequency with noise band width of 3.5 mc. Noise figure is measured by noting signal required to double zero signal noise power output of converter. Similar measurements made on average 1N21B diodes indicated noise figure of 16 db.

Maximum Ratings:

Average rectified current.....25 ma max.
Peak rectified current.....75 ma max.
Temperature range.....—50 to +75°C

...Other Applications, Too

For example, as harmonic generators to provide local oscillator injection from the low frequency local oscillator . . . As detectors in high frequency RF voltage measurements . . . and in low frequency circuits where a low impedance crystal is needed.

COMPLETE LINE OF GENERAL ELECTRIC WELDED GERMANIUM DIODES

General Purpose		Television	JAN	UHF	Quads	Transistors
1N48	1N63	1N64	1N69	1N72	1N73	SX-4A
1N51	1N75	1N65	1N70		1N74	Z-2
1N52						

You can put your confidence in—

GENERAL ELECTRIC

Fine Engineering

protects the long life inherent in Kerite Cable

Sound, resourceful engineering development is a contributing factor to the technical superiority of Kerite Cable.

Never-ending research in Kerite's engineering laboratories produces new, better ways to protect cable; new types of cable and new ways to make use of time proven Kerite insulation. Fine engineering, conscientious workmanship, and proper handling combine to protect the long life that is inherent in all Kerite insulated cables.

Kerite engineers will be glad to help you with your cable problems, whatever they may be. THE KERITE COMPANY, 30 Church Street, New York 7, N. Y. Offices also at 122 S. Michigan Avenue, Chicago; 582 Market Street, San Francisco; 714 W. Olympic Blvd., Los Angeles.

KERITE CABLE

Kerite Insulation—Your Cable's Best Life Insurance

HOW'S THIS FOR Accessibility?

ONE MAN can perform all routine maintenance jobs on this brand new line of Allis-Chalmers large motors. He can remove the upper halves of the end brackets and air baffles and reach right inside the motor with his vacuum cleaner or air hose. There is plenty of room to reach up back of the stator core through air discharge openings in the stator yoke.

Bearings Protected

The capsule-type sleeve bearings need not be opened up and exposed when the end bracket halves are removed. The bearings are protected from abrasive dust and dirt while the motor is being cleaned. This eliminates the work usually required to dismantle the bearing, clean and reassemble it during routine maintenance.

Easy Installation

Large stator air discharge openings with removable louvers allow ample room to use an electric or air drill for doweling and bolting the motor to the foundation. These large discharge openings plus adequate air intake openings in the end bells provide cooling air at low velocities.

Sleek Appearance

You'll be proud of the appearance of the new Allis-Chalmers motor in your plant, too. Clean, simple lines and smooth contours give outward confirmation of its inner strength.

These new design Allis-Chalmers drip-proof and splash-proof bracket bearing squirrel-cage induction motors are built in sizes from 60 hp at 300 rpm to 1500 hp at 1800 rpm. Ask your Allis-Chalmers representative to show you the details of this exceptional new motor or write Allis-Chalmers, Milwaukee 1, Wisconsin for Bulletin 05B7542. A-3251

ALLIS-CHALMERS

A page from the note-book of Sylvania Research

Color Television Research Accelerated by Study of Color Phosphors in Demountable Vacuum System

Sylvania's physicists, chemists and engineers have carried out fundamental research and development on color television tubes for a considerable period of time.

These basic investigations into practical color television tubes for home and industry have been conducted at Sylvania's Research Laboratories at Towanda, Pennsylvania, and Bayside, New York. Typical of the exceptional facilities and advanced research techniques used at the Sylvania laboratories is the demountable vacuum system shown in the photo.

Developmental samples of phosphor screens for color television tubes may be placed in the tube for study and test. Similarly developmental models of three-color electron guns may be placed in the neck of the demountable evacuated envelope and characteristics studied.

This continual basic research has enabled Sylvania to pioneer in providing the television tube industry with a complete selection of phosphors for color picture tubes. It has also paved the way toward more advanced research into the design and construction of color television tubes and circuits. It is typical of Sylvania's never-ceasing emphasis on *productive basic research*.

The operator is observing a spot of light on the phosphor screen of a developmental color television tube. By varying voltages applied to a three-color electron gun inserted in the demountable vacuum system, she can obtain data useful in improving both phosphors and gun designs for color television tubes.

SYLVANIA ELECTRIC

RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

Continuing Technical Leadership

T. G. LeCLAIR
PRESIDENT AIEE

ENGINEERING was used for military purposes in early Biblical times, but it is only within roughly the last 100 years that it has been used materially for civilian purposes. In the last 30 years, the engineering profession has become a prominent segment of the population. The engineers are looked to for leadership not only in war time but for technical progress in developing the tools for mass production and for the comforts of living. Do we realize the profession has also acquired a responsibility to continue this leadership in the future? If so, we should look carefully at the recent trend in the number of men entering engineering colleges.

By 1954 there will be only 15,000 engineering graduates. President LeClair discusses the reasons for this trend of fewer men entering the engineering profession, and suggests four thoughts for consideration by members.

In 1940, approximately 1 in 40 of the high school graduates entered engineering college. By 1947, due to the wartime technical progress and to the enthusiasm produced by the returning servicemen, the entering enrollment increased to about 1 in 20. The sharp increase in the total enrollment in engineering colleges is shown in Table I which shows that the number of first degrees granted rose from 11,000 in 1939–40 to approximately 48,000 in 1949–50.

Apparently, this sharp increase in engineering enrollment and in new graduates started a rumor or fear that there would soon be a surplus of engineers. Many of us did not realize the startling impact of this rumor. Now we learn that the number of high school graduates entering engineering college in 1950 has dropped to about 1 in 50.

The word "rumor" is used advisedly because apparently the surplus did not materialize and practically all of the 1949–50 graduates were absorbed promptly in jobs to their liking. The absorption of this larger number of graduates within a very few months is strong evidence that industry will continue to require a large number of engineers in the future for continuing technical progress. A drop in the number of new enrollments or of graduates for a single year need not be an alarming symptom, but a continuation of this trend could have a serious effect upon the country's future. It is the young engineers upon whom industry depends for the new ideas and for the carrying out of the detailed planning which is necessary to technical progress.

With the current enrollment of engineering students, the prospects for engineering graduates, as estimated by the American Society for Engineering Education, are as follows (first degrees from Engineers' Council for Professional Development accredited curricula colleges only)

1951	33,000
1952	22,000
1953	18,000
1954	15,000

What is the meaning of this trend of fewer men entering the engineering profession? Is it an anticipated lack of opportunity? Is it a relatively low rate of pay in the profession? Is it lack of available material? Recent experience has shown that there is no lack of opportunity when four times the normal prewar "crop" of graduates can be absorbed so readily. It is also interesting that this large number of graduates was absorbed without any drop in the rates of pay offered to new graduates. It does not seem reasonable that something strange is happening to the population, whereby there should be any decrease in the proportion of young men who have the necessary attributes and abilities to be trained for the engineering profession.

May I suggest the following thoughts for you members who constitute the leadership of the profession and who

Abstract of an address presented at the Winter General Meeting, New York, N. Y., January 22–26, 1951, during the General Session on January 22.

T. G. LeClair is chief electrical engineer, Commonwealth Edison Company, Chicago, Ill.

Table I. Engineering Undergraduate Enrollment

(Institutions in United States Only)

Year	Freshman	Sophomore	Junior	Senior	Fifth Year	Part-Time and Evening	Total	Number of First Degrees
1940	33,175	24,242	20,120	16,310	985	13,459	108,291	11,358 (1939–40)
1947	57,507	71,615	48,227	32,369	1,846	18,616	230,180	18,592 (1946–47)
1948	47,672	52,949	59,945	45,695	1,924	17,932	226,117	27,460 (1947–48)
1949	36,508	35,648	41,695	50,991	2,326	13,478	180,646	41,793 (1948–49)
1950	29,394	27,242	30,957	37,707	3,150	14,504	142,954	48,160 (1949–50)
1951								33,000 (Estimated)

have the best interests of the profession and public at heart:

1. Engineering is a specialized field which requires an analytical mind and other special abilities for success and progress. Therefore, the profession will not profit if large numbers of unqualified men are drawn to it solely because a temporary shortage creates unusual opportunities in the field. On the other hand, the profession and the public can ill afford to put any limit on the number of qualified young men being admitted in an attempt to make the profession exclusive.

2. The engineering approach can be used in so many ways in every part of industry that no qualified young engineer need fear that there is a lack of future opportunity for advancement.

3. Whether we are presently to be engaged in an economy which is largely military, largely civilian, or any combination thereof, there is a steadily increasing need for well-trained men in engineering.

4. Even with urgent military needs, it is important that the flow of young men into technical training be continued. We do not know whether the emergency may be long or short, but is it not reasonable that qualified young men can be of greater service training in their specialty than training for general service, whether or not they are under military control?

Each of us is an emissary of the profession in our informal discussions with relatives and friends, high school instructors and principals, and in vocational guidance interviews. Therefore, let us not be swayed by any false rumors that there is a surplus of engineers from some of the figures which were published six months to two years ago. Let us also not go to the other extreme and think that because of the trend to smaller numbers of engineering students, there will be such a shortage of new blood that engineering faces a gold rush for unqualified men.

In discussing future prospects with students and their advisors, can we concentrate on the fundamental that engineering presents a remarkable opportunity for a full and serviceable life in a profession which occupies a growing importance in the economy of the country? No person can accurately predict the exact number of jobs to be available in a particular field in a particular year. We can truthfully say that any qualified young man may enter an engineering college without any fear that the profession is approaching a saturation point.

The country needs technically trained young men. We cannot afford even for a single year to stop the flow of young men from high school into engineering training. Whether their status in training is to be military or civilian is less important than the fact that they certainly will be needed as soon as they are trained. There is not only an opportunity for these young men in the field, but a necessity on the part of the country to preserve its leadership.

High-Current Generator Shipped to India for Lightning Research

Modern research developments and design techniques have been incorporated in a new high-current impulse generator shipped to the Indian Institute of Science, Bangalore, India, by the General Electric Company's Transformer and Allied Product Divisions, Pittsfield, Mass.

This new research aid will be used to extend investigations of heavy surge currents and their effects on electric apparatus. The generator will simulate the currents of natural lightning discharges. Rated at 100,000 volts, 6 microfarads, 150,000 amperes, the high-current impulse generator consists of 48 capacitors rated 50 kv, 0.5 microfarad. These capacitors are mounted on shelves arrayed in an open square to facilitate a direct discharge into the test specimen which will be placed in the test cabinet located in the center. This arrangement also facilitates observation of the specimen while it is undergoing tests.

The measurement of the high currents this machine is capable of generating requires special high surge current shunts arranged in a concentric design, which are accurate to within 1 per cent up to 400 kilocycles. All supplementary equipment necessary for the correct operation of the impulse generator was also shipped.

The Critical Shortage of Engineers

S. C. HOLLISTER

OUR COUNTRY is once again obliged to arm in an effort to preserve peace, and to prepare for attack if it should come. No thinking person fails to grasp the fact that we are greatly outnumbered and that our chances of survival are dependent upon our ability to outdesign, outdevelop, outproduce, and outperform our enemies. At the same time that we are preparing for possible large-scale war, we must maintain, on a more efficient basis than ever before, our civilian functions. Moreover, we must prepare for eventual attack on our cities and on our industries and for the invasion of our homeland.

World War II brought to public attention the extent of the contribution to the war effort of the scientists and engineers. We could not have fought, much less won, that war without the vast equipment planned, developed, built, and operated by engineers. Not only have the engineers provided the country with the labor-saving devices, the means of transportation, communication, production, and distribution in peacetime, but they have also provided the special versions of all these services for war. The engineers design, develop, produce, and operate the ships, the planes, the guns, missiles, rockets, and ammunition, the tanks and armored vehicles, the radio, radar, sonar, loran, and other devices of communication and detection, the vast transportation facilities needed in warfare. They are clearly indispensible.

Unless drastic action is taken to increase the supply of engineering freshmen and to continue the training programs of World War II, there will be a cumulative shortage of over 40,000 engineering graduates by 1954. On the basis of Dean Hollister's report, the Engineering Manpower Commission of the Engineers Joint Council recommended a 4-point program to the National Security Resources Board (see news item on page 179).

But we are short of engineers. As we advance in the war preparations the shortage will be greater. As one contemplates the dependence upon engineers in the task before us, the seriousness of a shortage in this part of our manpower becomes evident. It comes about because there has been a falling off in enrollments in engineering colleges, largely due to a widely and erroneously held belief that engineers were in oversupply. The shortage will deepen if engineers are drafted or called up as reservists and used in positions for which engineering training and experience are not mandatory.

Figure 1 presents the essential factors in the outlook for supply of engineering graduates. The lower curve shows the annual output of the engineering colleges of the country for the academic years 1935–36 to 1950–51. It shows that from 1942 through 1945 the country, through its mistaken manpower policy, all but stopped the operation of engineering education. That is the reason why industry today is not successful in finding critically needed engineers with five to ten years' experience. They were not produced at the rate they should have been.

Beyond 1950 a dotted line shows the estimated number of graduates to be expected if the schools operated without any withdrawals by Selective Service. It represents the most optimistic production possible, at least until 1954, since all classes graduating up to that year are already enrolled in the colleges.

Since the number of graduates depends upon the number entering the colleges, the curve of freshmen is shown. Again is evident the low enrollment of freshmen of the war years, many of whom were taken out of college for military service. Following the war, the veteran benefits program brought the unprecedented number of 91,000 freshmen into the colleges in the fall of 1946. These did not come direct from the high school graduations in that year, but represented an accumulation of high school graduates who, for several years, had not been permitted because of the draft to proceed with college training. Since 1946 the numbers of freshmen have fallen rapidly until in 1950 there are enrolled about 30,000.

Beyond 1950 there is shown a dotted line indicating estimated freshman enrollment. This estimate was made before the Korean War, and was based on normal peacetime expectancies. It is seen that the actual enrollment for 1950 did not reach the estimate, due largely to widespread rumor that the engineering field was oversupplied.

The present situation already shows tightness in all fields, and critical shortages in many. Industry has absorbed the last two graduating classes of nearly 50,000 each and is hotly contesting for the 30,000 that will graduate in 1951. Many of the graduates are in Reserve Officers Training Corps programs and may thus go direct to military service. A large number have draft postponements and will be subject to call in June, if not before. Still others are veterans.

On August 3, 1950, the Secretary of Labor placed all branches of engineering on the list of critical occupations. In all the major branches, the shortage of engineers is becoming progressively more critical, especially in aeronautical, chemical, electrical, and mechanical manu-

Full text of a report presented to the Engineering Manpower Commission of the Engineers Joint Council on December 18, 1950.

S. C. Hollister is Dean, College of Engineering, Cornell University, Ithaca, N. Y.

facturing fields. Men with a few years of experience are almost unobtainable.

In normal peacetime it is generally accepted that at least 20,000 graduates are required annually. In the present situation it should be recalled that industry has absorbed 50,000 engineers in each of the last two years; but some of these certainly take the place of those that could not be hired in war years because in those years they were being produced only in small numbers. Industry, however, does not have all it needs; and the military requirements have not as yet been taken. Thus it appears that the minimum annual need is not less than 30,000 engineering graduates with use for many more if they should be available.

How do we obtain not less than 30,000 graduates yearly? First of all, to do so requires an annual input of 60,000 freshmen. This is about double the number entering engineering schools this year. How may twice as many high school graduates be attracted to engineering schools? Are there that many among the high school graduates who have an interest in engineering and who, at the same time, have the necessary aptitude and abilities?

The numbers of male and female high school graduates anticipated are shown at the top of Figure 1. It appears that between 1950 and 1958 there will be a 10-per cent dip in the numbers graduating so that the range is between 1,250,000 and 1,130,000. We clearly cannot rely, therefore, upon an increase in output of the high schools to solve the problem.

Except for the war and immediate postwar years, which were abnormal, the numbers entering engineering schools since 1935 range from 2.7 to 3.1 per cent of the total high school graduating classes. On the basis of an average high school output of 1,200,000 boys and girls, 5 per cent would be required to produce 60,000 engineering freshmen. This is about 10 per cent of the boys graduating from high school. There is some doubt whether the combined factors of aptitude, ability, and interest would be found in so high a percentage. It seems possible that the 60,000 freshmen shown as needed on the chart may be at or above the available number that can be expected to enter engineering. This brings home the fact that there is not, and there cannot be developed, an inexhaustible supply of engineering talent, but instead the supply is sharply limited.

Nevertheless, it is essential that all available avenues of information be used to acquaint the high school principals, high school guidance counselors, and the high school students themselves with the shortage and consequent need of engineers in all categories. It is vital to our security and welfare that such important information reach these persons.

What is significant to industry in the picture here set forth? It means that there will not be young replacements for engineering jobs vacated by the calling of reservists or of draftees. There will be only a partial supply of young engineers for new jobs as conversion, retooling, and war production may require. Intercompany pirating will only add to the difficulties of staffing. Robbing the colleges of faculty members for industrial jobs will surely dry up the supply and reduce the quality of training given by the colleges.

It will be essential for industry to re-examine the functions of the engineering personnel and to make certain that each engineer is being used in the most effective manner possible. No engineer should be used in positions others can occupy as well. Supporting personnel, requiring less training and experience, should be used to spread as far as possible the effectiveness of each engineer. Even competent supporting personnel will be tight. It will be necessary to begin in-service training of such personnel, and to engage women as far as possible. The training programs of the last war will need to be re-established.

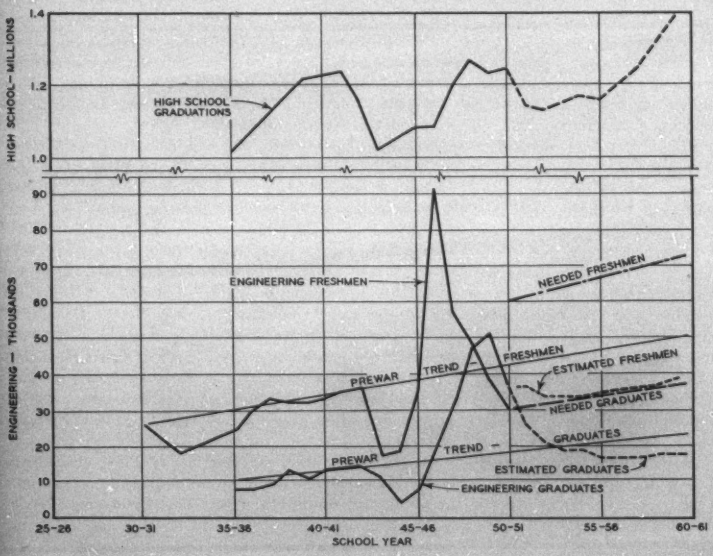

Figure 1. Outlook for the supply of engineering graduates. Actual and estimated enrollment by the United States Office of Education; needed students estimated by Dean Hollister

None of these steps can be put off. The organization of industries must be streamlined now.

Government agencies, including the armed forces, must take cognizance of the situation. Plans must be developed whereby the engineering manpower needs of the services and of industry may be so co-ordinated that both will be appropriately served from the limited supply. Industry has the job of supporting the military. To assume that the military needs are paramount or exclusive would be a form of national suicide. A careful planning for utilization of men with engineering training and experience only in categories where such training and experience are mandatory should be undertaken; although such probably cannot be wholly achieved, it is in the interest of the total effort that such an objective be approached as nearly as possible. Sound policies relating to deferment and the calling of reservists must be promulgated with the objective of maintaining a balanced utilization.

It is reported in the technical press that the Russians, in their current 5-year plan, are scheduled to have produced 150,000 engineering graduates by the end of 1950. This matches our own output for the same period. During the next five years, however, we will drop by one-third unless drastic action is taken to increase the supply of engineering freshmen and to continue the training operation in full force.

Obtaining Safety in Experimental Electrical Laboratories

C. F. DALZIEL
MEMBER AIEE

THE PRESENCE of electrical hazards and the conditions inherent in the operation of experimental laboratories suggest the desirability of developing policies and procedures aimed at raising the level of safety in industrial and educational laboratories. Experimental laboratories may be divided into three general types, industrial, research, and instructional. Instructional laboratories may be vocational, or junior or senior college level; they are places where large numbers of students first become acquainted with laboratory techniques. Research laboratories may be situated in educational, commercial, or other organizations, but in any case can be regarded as those places where advanced instruction is carried on or where investigations of a highly technical nature are conducted, such as investigations of high-voltage or high-frequency phenomena or other work utilizing highly specialized apparatus. Industrial laboratories may be considered as including a wide range of facilities where operators may be semi-skilled and where testing is usually of more or less routine nature.

Although the potential engineer often gets his first practical knowledge of electricity in a school laboratory, few safety precautions are taught in these laboratories. Suggestions are given here for increasing safety awareness and decreasing hazards in experimental electrical laboratories of schools and industrial plants.

Prevention of accidents requires a great deal more than mere accumulation of knowledge and assignment of accident prevention responsibilities. Raising the level of safety in experimental laboratories requires the active co-operation of many individuals. In educational laboratories, for instance, the passive attitude of many professors to safety matters may be reflected in the attitude of the teaching assistant and thus passed on to the students. It may be taken for granted that there is a difference in the practicability of prescribed safety requirements for commercial and educational laboratories, but this does not explain why regulatory bodies so often refrain from assisting educational institutions in eliminating hazardous conditions and in promoting better practices. The breach in safety consciousness between the practicing engineer and the manufacturers of commercial equipment on the one hand and the educator and the manufacturer of experimental laboratory apparatus and instruments on the other must be bridged. Raising the level of safety in experimental laboratories and the anticipated future reduction of industrial accidents requires the active support of several branches of the profession.

The primary objective of safe procedures and practices is to exterminate the causes of accidents. The causes are

Full text of a conference paper presented at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Fifth in a series of articles on safety. See "Perception of Electric Currents," C. F. Dalziel, T. H. Mansfield (*EE Sep '50, pp 794–800*), "108 Are Missing," E. G. Hunt (*EE Oct '50, pp 919–21*), "Safety Testing of Electronic Equipment," O. G. Wedekind (*EE Nov '50 pp 997–1000*), "Electrical Work Injuries in California Industries from 1940 to 1949," E. E. Carlton (*EE Dec '50 pp 1076–7*).

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The writer wishes to acknowledge and thank his associates for their many helpful suggestions and comments in the preparation of this article.

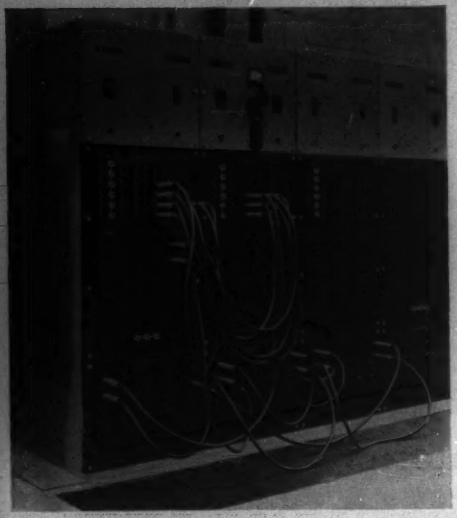

Figure 1. This laboratory switchboard is equipped with plastic-encased air circuit breakers. The front of the switchboard is made of ebony asbestos and the energized part of the receptacle is recessed one-fourth inch

of three types. The poorly trained man may be injured because he is completely unaware of the existence of a given hazard. The advanced student may become involved in an accident because he is not alert to a known hazard. Any worker may suffer serious injury because he disregards an obvious hazard. Whatever the cause, the laboratory supervisor assumes grave responsibilities for the safety of his personnel, and in case of serious injury he may find himself suffering remorse and loss of professional prestige, or, if his neglect is gross and obvious, criminal charges and loss of his job.

For purposes of this discussion it may be assumed that all permanent equipment in a laboratory has been installed according to prescribed safety standards, and that the areas of hazard are associated with laboratory switchboards and portable or semipermanent installations of machines, transformers, switchgear, instruments, and related devices. Such equipment is usually connected with portable leads, and either because of necessity or convenience adjustments or changes in connections are often made when the equipment is energized.

In instructional laboratories one of the difficulties of enforcing safety arises from the fact that in large institutions a laboratory class may consist of 12 to 20 students under the direct supervision of a teaching assistant. Although care is taken to make sure that the supervisor is a man of promise, it is likely that he has had little practical experience and this may be his first experience in assuming authority. The sizable group, limited experience of both students and supervisor, and youth's inherent tendency for horseplay contribute to potential hazards. An essential step in coping with this situation is the scheduling of a regular period at the beginning of the laboratory course for discussion, preferably with demonstrations, covering the operation and adjustment of circuit protective devices, safe laboratory practices, location of first-aid kits and fire extinguishers, effects of electric shock on man, rescue of a victim from the circuit, and approved methods of resuscitation.

In research laboratories hazards due to the higher voltages frequently used are somewhat offset by the smaller group handling equipment and to the greater competence of both researchers and supervisor. Where high-voltage equipment is used (that is, voltages in excess of 600 volts), warning signs, safety-interlocks, and an adequate supply of barrier tape and rubber goods maintained in good condition must be provided. All noncurrent-carrying parts, such as machine frames and instrument transformer secondary circuits, must be effectively grounded. Perhaps the most pressing hazard in such places is the tendency for a researcher to seclude himself and to work alone for hours, often late into the night. No man should be allowed to work on energized high-voltage high-power equipment out of sight of associates. Although it is essential that warning signs be placed at appropriate locations, the use of such warnings must be limited, as there is truth in the old saying "familiarity breeds contempt."

Although a painstaking effort must be made to reduce hazards to as low a level as practicable, acceptable minimum standards must be based upon the conditions existing in the particular laboratory considered. For example, some of the practices which should be prohibited in vocational or junior laboratories might be considered tenable

Figure 2. A 100-ampere tapered plug with self-protecting spring-operating insulating sleeve shown in two positions

in research laboratories, in which case they should be recognized as a normal risk of the venture. Furthermore, after a definite period of training a young man reaches the status of a properly qualified or authorized person, and the relative hazard of a given situation may change accordingly.

For economic reasons safety requirements must be kept within reasonable limits and confined to areas where real

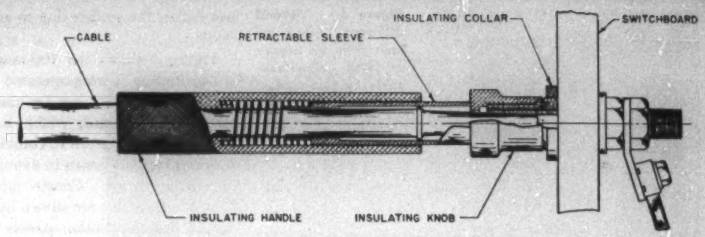

Figure 3. Construction of self-protecting plug and knob binding post

hazards exist. Certainly no effort or expense should be spared in the prevention of accidents, but it is essential that potential hazards be carefully evaluated. Money should not be spent in areas where the possibility of injury is very remote.

In educational institutions, the prevention of student injury is important, but a greater purpose is to make each student safety minded. The most certain road to reduction of industrial accidents is to create safe thinking and working habits during the training of the young engineer. Although reduction of electrical hazards is essential, it would be a grave mistake to eliminate all hazards during the training period. Such a procedure would inevitably result in lack of appreciation that industrial hazards exist, and it would most certainly lead to an unhealthy attitude regarding safety in general. It is important that the young man, early in his training, be led to recognize the potential hazards of his chosen profession. However, this important consideration certainly does not constitute justification for the continuation of hazards which can be prevented.

The general safety problems in experimental laboratories are illustrated by the procedures in instructional laboratories, where operations include demonstration, testing, and circuit synthesis. Although demonstrations may be effectively conducted using totally enclosed apparatus, experiments involving testing and synthesis often require ready access to energized components. Experiments which last only three or four hours may require several changes in connections and adjustments in addition to measurements at various points, and in many cases these operations must be made while the apparatus is energized. Enactment of regulations requiring that all equipment be totally enclosed, or dead-front and dead-back, would result in serious impairment of instruction. Quite aside from the undesirability of impairing instruction, elimination of all hazards would fail to develop the student's conviction that electricity is potentially dangerous, and it would fail to develop proper respect for bare copper. As a result, many educators feel that it is essential that the student be placed in proximity to low-voltage circuits, busses, contactors, commutators, and the like.

The first requirement in a school laboratory is that all permanently installed laboratory equipment comply with the electrical safety code of the state. However, it is difficult, if not impossible, to apply prescribed rules to much of the equipment used in laboratory instruction, so the second step is to classify hazards and to study of ways and means of reducing them. A classification of hazards in experimental laboratories follows.

1. Electric shock hazard due to casual contact
2. Let-go hazard due to gripping contact
3. Short-circuit hazards
   A. Circuit opening devices—interrupting capacity
   B. Circuit closing devices—trip free action, and sputtering of molten metal
4. Arc hazards
   A. Harmful radiations
   B. High temperature
5. Mechanical hazards
   A. Overspeed
   B. Exposed couplings
   C. Tripping over leads or equipment
   D. Defective tools or equipment, or improper use of them.

These hazards are approached in the following manner: It is concluded that the shock hazard from casual contact with energized parts has to be reduced, and it is also concluded that electric shock hazards cannot be completely eliminated. Means of reducing the hazard are receiving continuous study on an individual item basis, but it is believed that this hazard must be accepted as one of the risks of experimental laboratories.

In contrast, the let-go or freezing hazard due to grasping energized conductors, especially bare terminals, must be eliminated. Insulation of all terminals which might be grasped presents a formidable but not an insurmountable task.

Short-circuit hazards and hazards due to electric arcs must be eliminated as far as practicable. In the control of these hazards a distinction is made between switches which may be closed against short circuits and those which are used to interrupt or by-pass load currents only. The shock hazards from exposed switches designed to interrupt or by-pass normal load currents, such as ammeter cutout switches, knife, dial, or fan switches on rheostats and resistor loading devices, and so forth, are considered one of the normal hazards of laboratory instruction. In contrast, devices which may be closed against short circuits must be given very careful consideration. All open knife switches which might be used for this purpose must be replaced with enclosed externally operable types. Circuit breakers must be trip-free and have adequate interrupting capacity, and the exposed arcing contacts of portable air circuit breakers which are used at eye level or below must be

Figure 4. Several different types of leads can be accommodated simultaneously by this type of distribution panel

equipped with hoods or arc chutes to protect against the heat of the arc and harmful radiations. Protection against arc hazards must also be provided on switches used to break highly inductive circuits, including ordinary knife switches often used for field switches.

Overspeed and exposed couplings are generally recognized as the most serious mechanical hazards of rotating electric machinery. All d-c machines should be protected against overspeed by some speed-sensitive device arranged to give positive protection. Couplings should be smooth and free from projecting parts or provided with permanent guards. Many accidents may be prevented by tidy work habits. Good housekeeping, such as keeping unused leads properly racked, tools in their proper places, reporting defective tools or equipment, and arranging equipment and leads to permit access without danger of tripping or stumbling, will eliminate many hazards.

Discussion of a few items will indicate some corrective measures. The senior laboratory switchboard at the University of California is shown in Figure 1. This type of switchboard is familiar as the general layout has been used in experimental laboratories for years; however, one or two points deserve mention. All power sources are protected with plastic-encased air circuit breakers having both thermal and instantaneous magnetic trip mechanisms. The maximum voltage is 480 volts, which is available to the instructor for driving prime movers, but outlet receptacles not in use are blanked out with insulated plugs to prevent accidental use of this voltage. The maximum voltages of the other source outlets are 240 alternating volts and 250 direct volts. Although the switchboard and associated accessories have been approved as complying with the safety requirements of the state, a person could, by deliberate act, contact either the energized part of a receptacle which is recessed one-fourth inch inside its bakelite cup insulator, or he could contact the tip of a 100-ampere plug lead while the other end was energized. This hazard, although considered of minor importance, determined the choice of ebony asbestos rather than steel for the panels containing the receptacles. A rubber mat is provided in front of the switchboard to reduce the proximity of grounded objects which might form a return circuit. Another advantage of insulated panels is that the tip of an energized plug accidentally striking the panel cannot deface the surface due to arcing, except at the holding bolts.

Figure 2 shows the 100-ampere tapered plug with its self-protecting spring-operated insulating sleeve in two extreme positions. Besides almost completely eliminating the freezing hazard, which is the objection to the unprotected plug, the sleeve confines the arc, and its expulsion action materially assists in extinguishing an arc when errors in plugging occur. Construction details of the plug and a knob binding post are shown in Figure 3. Figure 4 shows one of the distribution panels which are spaced at convenient intervals throughout the laboratory. The knob binding posts accommodate several different types of leads simultaneously. During normal conditions ordinary wire is not used for leads in instructional laboratories; however, the grooves in the brass locknuts accommodate wires up to about Number 6 and permit rapid expansion of leads during periods of heavy enrollment, such as occurred shortly after the close of the war. It is often expedient to use rubber-covered wire for leads in research laboratories and for parts of circuits which are to be left wired up for extended periods.

The hazards of control equipment have been given serious attention for several years; see Figure 5 for an example of a typical experiment setup. This equipment may be both live-front and live-back, as many measurements and adjustments are necessary, and some of the work must be done while the apparatus is energized. The devices are used for senior and graduate instruction, and the maximum voltage is 240 alternating volts or 250 direct volts. Although the freezing hazard should not be serious, the shock hazard due to casual contact is high. Either instruction in this important class of equipment should be deleted from the curricula, or the hazards should be recognized and accepted. Because of the increasing importance of this class of apparatus it is desirable that the hazards be accepted as a calculated risk of instruction.

Figure 5. Typical experimental setup which necessarily has many shock hazards

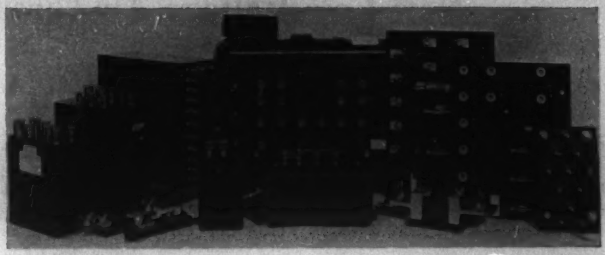

Figure 6. Commercial equipment on which brass binding posts will be replaced by insulated ones

Additional study is being given to the problem of achieving the maximum degree of safety without serious impairment of instructional values.

The foregoing represents but a start on the problem of reducing electrical hazards in experimental laboratories. The battle of safety can be won only by co-operative efforts of both users and manufacturers of laboratory apparatus, instruments, and devices. In Figure 6 are shown recently acquired commercial equipment and instruments equipped with brass binding posts, each of which is to be replaced with insulated binding posts to eliminate as far as practicable the freezing hazard due to accidental contact while energized. Several of the devices have insufficient spacing between energized parts; for example, the terminal board at the extreme right-hand side of the figure was removed from a 480/240-volt motor, and the clearances are not as they should be. As previously stated, corrective measures are being taken on an item-to-item basis, and it is anticipated that the level of safety eventually will be raised to an acceptable standard. It is obvious that much of this needless expense would be eliminated if the manufacturers would incorporate more safety in the design of equipment.

Suggestions for Safety in Laboratories

A person's reputation may be seriously injured if his lack of foresight results in accidents to himself or others.

Haste causes many accidents. Work deliberately and carefully. Check your work as you go along.

Determine positively whether the circuit is "hot" or "cold" before starting work.

Never touch an energized conductor with hands wet with water, perspiration, or chemicals. Never touch an energized conductor when your shoes are wet, when standing in water, on the ground, or on grounded objects.

When working on energized equipment, make a practice of always having an assistant within sight or calling distance.

All power circuits are dangerous. Do not work with voltages higher than 250 volts without taking extra precautions such as the use of rubber gloves, rubber mats, and tools with insulated handles.

When working on electric apparatus which is "hot," use only one hand as far as practicable. Keep the other off of all grounded objects.

Do not start to work on a high-voltage circuit until you have made certain that both the oil circuit breaker and the disconnect switches are open. Place warning signs on all switches that might be used to energize the circuit. Bond all line conductors together and connect them to good grounds placed between possible energy sources and the work location.

Never close a switch slowly or hesitatingly; close it quickly and positively.

Cultivate the habit of turning your face away when opening or closing disconnects or air circuit breakers. Do not avert your face and then grope for the switch or circuit breaker. Use extreme care when breaking highly inductive circuits, as dangerously high voltages are likely to result.

Remember that burns from arcs may be very severe. Guard against arcs as well as high voltage.

Avoid the possibility of exposing your eyes to electric arcs, as they are powerful generators of ultraviolet light, including wave lengths which may cause serious and painful injury to the eyes, even with short exposures.

Be careful to keep watch chains, finger rings, wrist watches, flashlights, metallic and metal-bound measuring rulers, and metallic pencils out of contact with energized circuits.

Do not use wires with poor insulation. Make sure that all splices and connections are securely made and properly insulated.

Do not, under any circumstances, open the secondary of a current transformer while under load. Current transformer secondary circuits must be worked with the secondary short-circuited. (Conversely, potential transformer secondary circuits must be worked open-circuited.)

Be careful to avoid the capacitance effects of transformer cases and other high-voltage apparatus. The frame of every high-voltage machine should be grounded. All conducting objects whose potential is not definitely fixed should be solidly grounded when in the vicinity of high-voltage circuits.

All capacitors should be discharged before working on associated circuits. The charge disappears from capacitors slowly, and interruption of the power supply should be followed by short-circuiting each capacitor before the equipment is considered safe.

Make all connections on the load side first, leaving source connections to the last.

Check all connections before energizing the circuit.

If smoke, fire, or heat give evidence of improper connections or short circuit, open the source switch before attempting to make corrections.

Do not take chances. If you are not certain of the proper procedure ask your superior for proper instructions.

New Low-Voltage Air Circuit Breaker

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THE GROWTH of modern low-voltage systems has advanced so far that now the low-voltage air circuit breaker must meet requirements which were unheard of ten years ago.

Low-voltage air circuit breakers which can close and latch against fault currents equal to the interrupting rating of the circuit breaker now are required. These circuit breakers also must have a short time rating equal to the interrupting rating. With such characteristics, a circuit breaker may be equipped with tripping devices of either the direct-acting or relay type to provide full selective tripping performance over the complete range of fault current.

Figure 1 illustrates a 3-pole 1,600-ampere 600-volt 60-cycle electrically operated air circuit breaker of 50,000 amperes interrupting rating with direct-acting series overcurrent tripping devices. This "DB Line" of air circuit breakers now includes interrupting ratings of 15,000, 25,000, and 50,000 amperes.

Pole units on this circuit breaker are so designed that the main current-carrying circuit and the secondary arcing circuit are of the blow-on type. The arcing circuit is arranged to enhance the transfer of current from the secondary contact to the primary or uppermost arcing contact. Wide bearings are provided on the contact arms to minimize any sidewise motion caused by interphase attractions and repulsions. Shunts around the hinges eliminate pitting and thus insure a minimum of friction.

Arc extinction is obtained by employing the deionizing principle in an arc chamber consisting of steel plates placed in the arc path perpendicular to the arc and ceramic arc shields in each side of the arc chamber. The steel plates provide the necessary magnetic action to pull the arc into the chamber and to cause the formation of a number of short arcs.

Interruption tests were conducted on this circuit breaker, mounted in a cubicle which had a steel partition $4^{1}/_{8}$ inches above the arc chambers and grounded to the circuit breaker frame and cubicle. Excellent interruptions were obtained with no failures.

The conventional insulating base was replaced with a strong steel framework on which individual pole units are mounted. Phase-to-ground insulation is provided by the base mold for the individual pole assemblies.

The circuit breaker frame, vertical panel, and operating mechanism are all at ground potential and thus provide the greatest possible protection to personnel.

An operating mechanism of the trip-free type is used on this circuit breaker. Low mass in the parts results in high-speed tripping. Molded insulating links on each pole unit provide the necessary dielectric between the operating mechanism and current-carrying parts.

High-speed closing is obtained by a d-c closing solenoid with a control relay designed for this particular duty.

Attachments which are self-contained subassemblies such as shunt trip, undervoltage trip with and without time delay, reverse current trip, alarm switch, auxiliary switch, key lock or key interlock, electric lockout, and operation counter do not change the over-all dimensions of the circuit breaker and may be added or changed readily in the field.

Current ratings of the circuit breaker may be changed in the field by replacing the series overcurrent tripping device with a unit of the desired current rating.

The circuit breaker is 19.5 inches wide and may be mounted in tiers of three in a 90-inch switchboard.

Numerous tests have been performed to establish the characteristics of this circuit breaker, such as the interrupting and short-time ratings and closing and tripping speeds. Total closing time is seven cycles, and the total shunt tripping time is 3.4 cycles on a 60-cycle basis.

Through the employment of a unique contact arrangement and a highly discriminating use of space and material, a new low-voltage circuit breaker has been provided which offers greater performance with a reduction in space and weight. The short-time rating has been raised to equal the interrupting rating of 50,000 amperes. The added ability to close and latch on this current permits tripping to be delayed throughout the entire range of fault current which, in turn, facilitates application to obtain the ultimate in selective tripping performance. A high degree of flexibility has been achieved in adapting the circuit breaker for drawout mounting and in adding or changing tripping devices or attachments in the field.

Figure 1. Complete electrically operated circuit breaker in closed position

Digest of paper 50-272, "New Low-Voltage Air Circuit Breaker with 50,000 Amperes Interrupting Capacity at 600 Volts A-C," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Electrical Instrumentation in Medical Research

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RECENTLY there has been a heartening trend in biological research toward closer collaboration between the physical and the biological sciences. This article is a résumé of a program of this nature being pursued at the University of Pennsylvania. In order that such a program be well balanced, research, education, and instrumentation are all required. These three topics are discussed and new technical developments are described.

Work done in the field of electrocardiography may be cited as one example of research. In explanation of the distribution of potentials on the body surface arising from heart action, an ingenious theory has evolved which is widely accepted. However, some of the fundamental postulates on which this theory is based are open to question. Chief among these is the assumption that for electrocardiographic purposes the body behaves as a homogenous volume conductor. Through the years, numerous attempts have been made to check this assumption both by measuring directly the resistivities of the various tissues within the body and by more indirect means. Investigators have reached widely differing conclusions from their experiments so that there is still no definitive answer to the question. This past work has been reviewed and evaluated and a series of experiments is under way which, it is hoped, will throw further light on the subject.

The educational phase of the program has been conducted at both the formal and the informal levels. Courses have been given in Radiologic Physics, Physics Applied to Physical Medicine, Electrical Instrumentation for Research Workers in the Biologic Sciences, Electricity Applied to Electrocardiography, and lectures on the physical aspects of radioactivity applied to medicine. So far, the education of the engineering personnel has been informal in nature, although formal courses for physical scientists interested in the biologic sciences are contemplated. It is felt, however, that the informal type of education for both engineers and medical men has been of considerable value, and one of the important justifications for the entire collaborative effort lies in the opportunity provided for education of this type.

The third phase of the program consists of the development of instruments for performing physiological measurements. The measurement of temperature, blood pressure, and volume rate of flow of blood are regarded as particularly important. Emphasis therefore has been placed upon developing instruments to make these measurements.

The thermocouple and the thermistor are the two transducers that seem to lend themselves most readily to this purpose. Of the two, the thermistor is the more sensitive and the necessary associated circuitry for producing a written record is less complex. However, the thermocouple can more easily be made smaller, so that for applications in which size is the limiting factor, a thermocouple is employed.

Figure 1. Complete fine wire thermocouple assembly with insertion needle and ice water bath. Hypodermic needle is attached to sliding crossbar. The needle is withdrawn to allow a fine thermocouple to contact surrounding tissue. A double exposure has been made to show the forward and withdrawn positions

Measurement of deep tissue temperature is such an application. To make this measurement, a hypodermic needle with a thermocouple inside it is introduced into the tissue. The hypodermic needle then is withdrawn, leaving the exposed thermocouple in contact with the tissue; see Figure 1. The needle should, of course, be as small as possible to avoid undue tissue damage and pain. For this purpose, a thermocouple of concentric construction was developed in which the outside diameter is approximately 0.0037 inch ($1^1/_2$ times the diameter of a human hair).

For measurement of knee joint and blood temperatures, a bead-shaped Western Electric Company thermistor was placed at the end of a thin polyvinyl chloride tube, having an outside diameter of 0.020 inch. This same style thermistor also has been incorporated in other housings suitable for measuring skin and rectal temperatures.

Detailed information may be obtained concerning the functioning of various parts of the blood circulating system by directly measuring the pressure of the blood within the heart and blood vessels. For this purpose a plastic tube, filled with saline solution, is introduced through a hypodermic needle into the vessel under study. The instrument end of the tube is led to a small chamber, one wall of which is a thin metal membrane. This movable membrane is spaced a short distance from a fixed metal plate, thus forming a capacitance. Small movements of the membrane, with respect to the fixed plate, are measured electrically as changes in this capacitance.

These devices bear witness to a new trend in science: the drawing together of the physical and biological sciences in the hope that mysteries that have thus far withstood the attacks of each science working alone can now be solved by collaborative investigation.

Digest of paper 50-209, "Electrical Instrumentation in Medical Research," recommended by the AIEE Committee on Therapeutics and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3-5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Chicago's New Ridgeland Station

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Newest addition to the Commonwealth Edison Company is the Ridgeland Station with an ultimate capacity of 600,000 kw. The result of long-range planning, the station has many modern features including centralized control, cyclone-fired furnaces, and hydrogen-cooled generators.

ON DECEMBER 7, 1950, the Commonwealth Edison Company of Chicago, Ill., dedicated its first completely new generating station in over 20 years. Ridgeland Station is planned for an ultimate capacity of 600,000 kw. Preliminary work was started in August 1947, and the first 150,000-kw unit was placed in service October 29, 1950. The second 150,000-kw unit is under construction and will be in service in 1951. The third and fourth units, already authorized, will require extension of the building to its ultimate capacity. Service is scheduled for 1953. The addition of the first Ridgeland unit brought the total net plant capability of the system to 2,802,000 kw.

This article covers the outstanding features of the station with detailed references applying to the installation for the first two turbine-generator units.

FUEL SUPPLY

THE STATION is located on the Chicago Sanitary and Ship Canal, see Figure 1. The waterway serves as a source of condensing water and also permits barging of the coal supply. Fuel for Chicago stations is supplied from the central Illinois coal fields, about 200 miles from the city. The economy of barge transportation permits transfer of coal reserve among stations on the waterway in time of need. Rail hauling facilities and a car dumper provide an alternate method of coal supply.

The coal-handling system consists of a traveling dockside bridge crane and conveyor belts and crushers, all making up an 800-ton-per-hour system. The entire system is controlled from one point, where a board shows, at all times, the operation of each portion of the system.

WATER SUPPLY

WATER SUPPLY for the steam generators and for general station use is obtained from Lake Michigan, about 10 miles away. Storage of 400,000 gallons at the station in two underground reservoirs assures adequate water at all times. The water treatment plant is designed for completely automatic operation.

Condensing water is drawn from the canal through a 15½-foot tunnel. Condensing requirements are about 445,000,000 gallons per day for two 150,000-kw units.

STEAM GENERATORS

THE CYCLONE-FIRED steam generators, two per unit, are rated at 730,000 pounds per hour each at 1,900 pounds per square inch and 1,050 degrees Fahrenheit. With this method of burning, the coal needs only to be crushed to about 1/4-inch size rather than pulverized. This method of firing produces a maximum efficiency of combustion with a minimum fouling of the boiler tubes and stack gases. Electrostatic precipitators are used to reduce the stack discharge to a minimum.

Because natural gas is available at times as an economic fuel, the boilers will be equipped for gas firing as well as coal firing. Electronic combustion control will regulate firing with coal or gas or a combination of the two. This system regulates fuel and air supply to maintain a predetermined steam supply. For flexibility of operation, it is possible to set any proportion of natural gas to coal consumption, and maintain the proportions under varying steam demand. All controls are located in the station control center.

TURBINE-GENERATORS

EACH OF THE FIRST two 150,000-kw units is supplied by two steam generators, with a total capacity of 1,460,000 pounds per hour at a throttle pressure of 1,800 pounds per square inch gauge at 1,050 degrees Fahrenheit. The four steam generators are connected to a common header. Each unit consists of a 50,000-kw 3,600-rpm high-pressure and a 100,000-kw 1,800-rpm low-pressure element normally operated cross-compound. The latter actually has an intermediate- as well as a low-pressure turbine on its shaft. Provision is made for independent operation of the low-pressure element by operating the boilers at about normal pressure and at suitably reduced steam temperature, and by having the steam go through a special throttle valve and governor that is used during such operation. This valve effects a suitable reduction in the pressure of the steam which is entering the intermediate turbine.

The hydrogen-cooled generators are designed for operation at 85-per cent power factor at 0.5 pound per square inch gauge. With hydrogen at 15 pounds per square inch, the rated capability of the unit will be 15 per cent higher or approximately 203,000 kva. Rated voltage is 13.8 kv. Each generator is provided with a motor-driven exciter. A third exciter serves as reserve for the generators of either the high-pressure or low-pressure elements. A diagram showing the 69-kv and 13.8-kv connections is shown in Figure 2.

D. L. Levine is senior engineer, Station Design Division, F. W. Beeman is assistant chief engineer, Calumet Station, and T. G. LeClair is chief electrical engineer of the Commonwealth Edison Company, Chicago, Ill.

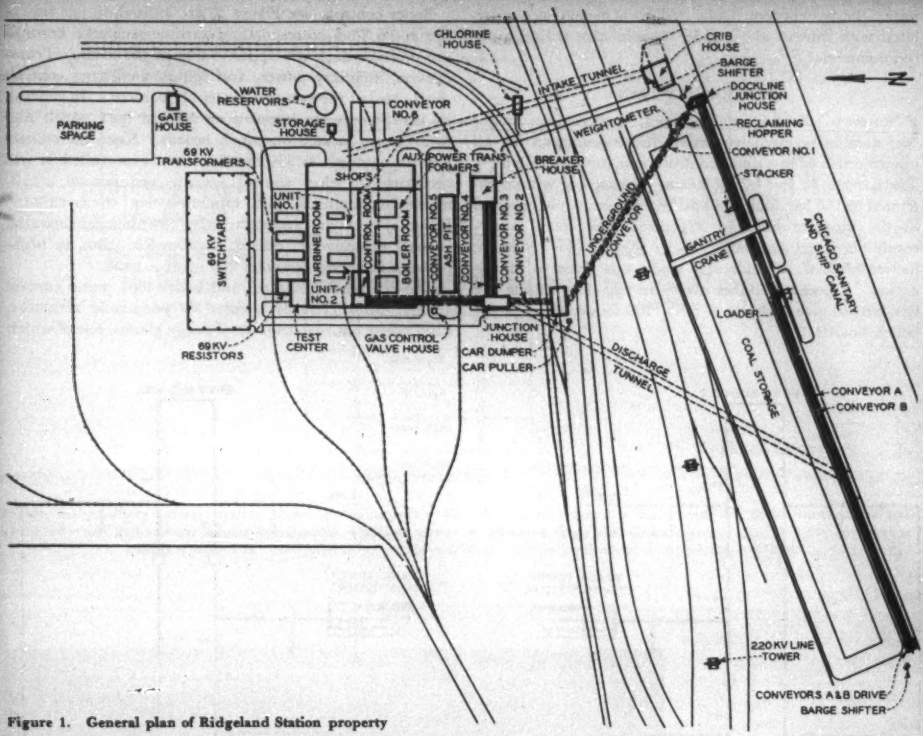

Figure 1. General plan of Ridgeland Station property

Automatic control of generator excitation has been designed for two functions. For normal operation, a preselected generator bus potential will be maintained under normal load variations. Automatic minimum-excitation apparatus will insure stable operation with relatively low field currents.

AUXILIARY POWER SUPPLY

ALL AUXILIARY POWER except one turbine-driven boiler feed pump and miscellaneous small auxiliary turbine-driven oil pumps is supplied from the electric system. For each unit, two 8,000-kva transformers are connected directly to the generator leads to provide power at 4,160 volts (see Figure 3). Duplicate transformers are connected to the 69-kv bus so that auxiliary power is normally taken directly from the generators but may be supplied from the 69-kv transmission system. The transfer is automatic in case of failure of normal supply. A zigzag secondary was used on the 13.2/4.16-kv transformers, so that with Δ-Y connection on all transformers, the auxiliary power supplies would be in phase.

General station auxiliary power is supplied from the 69-kv system. One 10,000-kva transformer is connected to each ring bus. The load is divided between these transformers on the 4,160-volt side, with automatic transfer in case of failure of either source of supply. Auxiliary equipment, driven by motors from 50 horsepower up to 3,500 horsepower, will operate at 4,160 volts; smaller equipment at 208 volts.

AUXILIARY POWER SYSTEM

THE AUXILIARY power system consists of five 4,160-volt substations and ten 208-volt substations. One 4,160-volt substation supplies large station auxiliaries as well as the six 4,000/208-volt substations for station lighting and miscellaneous small power. Two 4,160-volt and two 208-volt substations serve the power requirements of each generating unit.

The transformers feeding the 4,160-volt system are in compartments outside the building wall and are connected to the switchgear by a 3-phase metal-clad bus. Each substation has two parallel rows of switchgear connected by a bus crossing over the operating aisle. All switchgear is of the drawout type. The 4,160-volt circuit breakers are wheel-mounted. The 208-volt circuit breakers and contactors are stacked three high, with monorail facilities provided for handling removable elements. Cable is carried in open troughs in tunnels and in the cable rooms

under the switchroom floors. All switchrooms are ventilated with filtered air in order to minimize maintenance requirements.

CENTRAL CONTROL

Control of boilers, turbines, generators, major auxiliaries, auxiliary power, and transmission for all units is centered in a single control room, shown in Figure 4. The room is 40 feet by 96 feet at present, but will be extended to 160 feet long and will be approximately centered in the ultimate building structure. The room is air-conditioned and maintained under slight positive pressure for cleanliness. Considerable study was given to illumination. Fluorescent tubes above an egg-crate ceiling are designed to give a choice of 50 or 100 foot-candles on the bench boards.

Boiler controls (see Figure 5) are located on one side of the room and corresponding turbine-generator controls are positioned on the opposite side of the room. Transmission, auxiliary power, and station auxiliaries controls are located at the eventual center of the room. In general, all instruments are installed on vertical back panels and controls are located on bench boards. Since the control room is as much as 350 feet from items controlled, it was necessary to select control systems and remote instrumentation methods with minimum lag characteristics. Pneumatic relaying and electrical or electronic telemetering is used extensively. Steam, combustible gases, or high-pressure fluids do not enter the control room.

The combustion control and boiler feed pump control are electronic controls adapted to pneumatic actuators. Each boiler has two drum-level gauge glasses, one of which

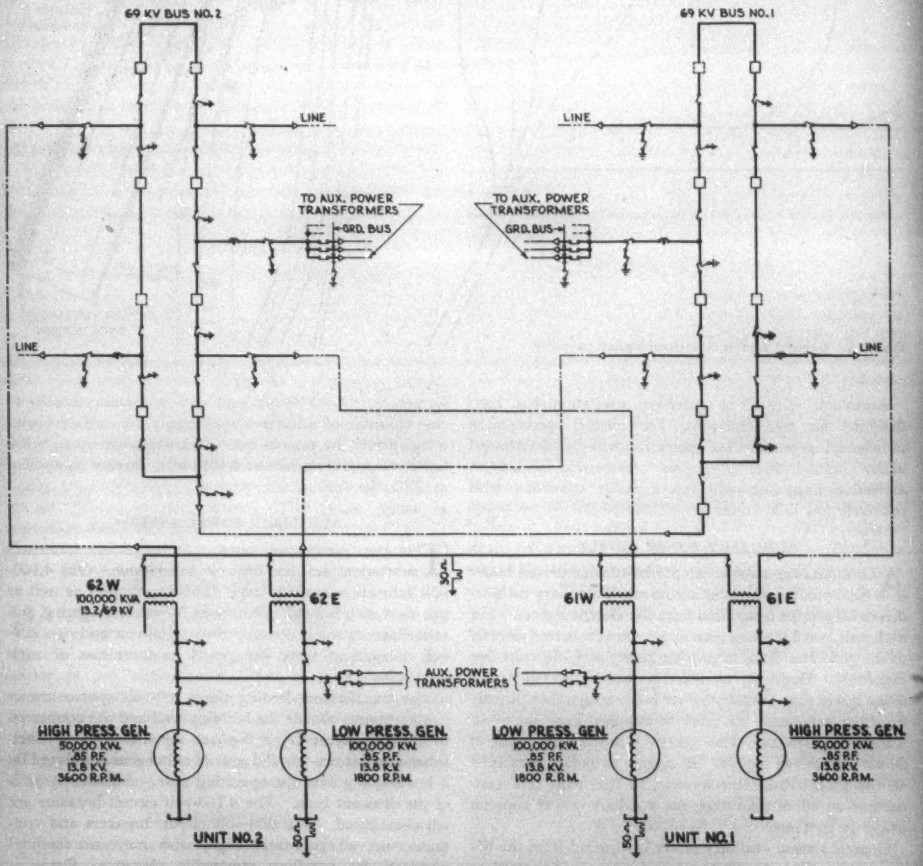

Figure 2. Electrical diagram showing the 13.8-kv and 69-kv connections

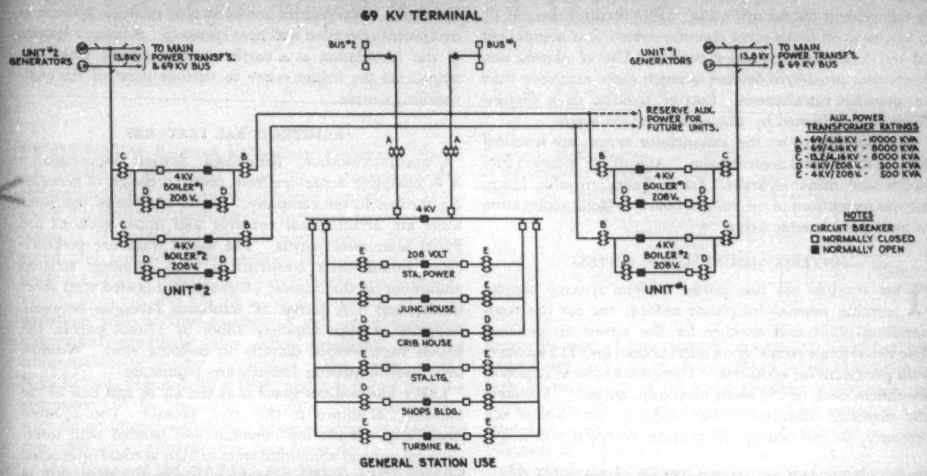

Figure 3. Auxiliary power system showing the supply from the 13.8-kv generator leads and the 69-kv terminal as well as the 4-kv and 208-volt arrangement. General auxiliary power is obtained from the 69-kv system; 50- to 3,500-horsepower auxiliary motors are connected on the 4,160-volt line; smaller equipment is on the 208-volt line

Figure 5 (below). A view of the control room showing the bench board and gauge board of one boiler

Figure 4 (above). One end of the control room showing equipment for the first unit. Boiler controls are on the left, turbine controls on the right, and electric controls at the end

is televised to the control room. This is supplemented by a telemetered drum-level recorder which is a component of the 3-element feedwater control. Use of alarms and automatic protective devices is much more extensive than in previous installations. Loss of ignition in a cyclone furnace is indicated by photocell-actuated alarm.

Audible alarms on the annunciator system are installed only in the central control room. Alarms are grouped into major and minor systems. Large "area" trouble lamps appear on sections of the control board to facilitate location of individual trouble lights.

INTERCOMMUNICATION SYSTEM

THE STATION has two public address systems supplementing normal telephone service, one for the coal-handling plant and another for the station in general. The two systems consist of 68 microphones and 115 speakers with provisions for additions. There are a total of 12 power amplifiers, each of 150 watts maximum output. Speakers are dispersed throughout the buildings and about the property, as necessary, to provide complete coverage. Generally, microphones are located at strategic spheres of equipment operation and near speakers. A unique feature of the installation is a carrier-current system which extends from the bridge crane to various parts of the coal-handling system.

Spider Framework for Rotor in Process of Being Welded

This 79-ton spider being welded at the East Pittsburgh, Pa., plant of the Westinghouse Electric Corporation is the inner framework for the rotor of one of the 108,000-kw waterwheel generators for the Grand Coulee Dam power plant. The rotor measures 31 feet in diameter and, when completed, will weigh 542 tons. It will rotate at 120 rpm

ARCHITECTURAL FEATURES

ARCHITECTURALLY, Ridgeland Station represents a complete departure from previous design of generating stations in the company. Lower sections of the outer walls are architectural concrete and upper sections are fluted aluminum panels. The metal walls are prefabricated double-sheet construction with 16-gauge striated aluminum on the outside, 18-gauge zinc-coated steel sheet inside, and $1^1/_2$ inches of insulating Fiberglas between. Supplied in approximately 2-foot by 12-foot panels, the panels were welded directly to building steel. Window sash and ventilating louvers are aluminum.

Office and utilities space is at the far or east end of the building, as shown in the cover picture. The 213-foot stacks with "bottle top" contour and banded with international red and aluminum were as high as could be erected because of the proximity of the station to the glide-path of the Midway Airport. Wind tunnel studies at the University of Michigan dictated the stack design and building contour. Sloping walls of the coal conveyor housing over the boiler house roof can be seen. The junction tower in the coal conveyor system is in the foreground.

LIGHTING

THE ROADWAYS on the property are lighted by mercury-vapor highway-type lights of 21,000-lumen capacity. The coal yard and dock area are floodlighted from two 100-foot towers to permit night operation of the coal system.

The turbine room and shops are provided with a combination of incandescent and mercury-vapor lighting. With each 400-watt mercury-vapor fixture 750 watts of incandescent lights are used. The effective light intensity is 25 foot-candles on the turbine room floor. This combination of lighting was found to give a close approximation of daylight.

Obstruction lights on the end stacks are mounted on hinged booms at the nozzle sections, and on swivel rings for all stacks at the mid section and nozzle sections to facilitate maintenance. Lights are controlled by means of photocells and duplicate circuits with automatic throw-over are provided.

CONCLUSION

THE NEW STATION is representative of the latest engineering advancements of the electric power industry. Long-range advance planning led to the acquisition of the plant site over 25 years ago. What was wasteland then is now the center of a rapidly growing industrial and residential load area. Structural design made use of the most economical materials and methods available at the time of construction. The output of the station that will be available by 1951 will be readily absorbed in the existing transmission system to satisfy the ever-increasing demand for electric power in the Chicago area.

Design of the Naval Research Laboratory Computer

D. H. GRIDLEY B. L. SARAHAN

THE NAVAL Research Laboratory Electronic Digital Computer (NAREC) is to be a general-purpose electronic digital computing machine capable of high-speed computations with binary numbers having a precision of 44 digits (about 13 decimal digits). The high-speed and precision characteristics of the computer will make it especially valuable not only for reduction of experimental data but also for the solution of systems of linear equations with a large number of unknowns, nonlinear differential equations, and other problems involving computations of similar magnitude. The design of the NAREC was begun in July 1949, and it is hoped that the computer will be placed in operation by January 1952 with an additional six months being required to place the computer on an efficient operating schedule.

The circuits of the NAREC, see Figure 1, are divided into five sections: input section, arithmetic section, storage section, control section, and output section. In addition, equipment is provided for preparing the magnetic tapes used by the input section and for transcribing the information recorded on the magnetic tape by the output section. The main unit of the NAREC is 30 feet long, 8 feet high, and 3 feet wide. It consists of two magnetic tape readers (input section), four magnetic tape recorders (output section), 45 cathode-ray tubes (electrostatic storage portion of the storage section), and 1,800 vacuum tubes and 6,000 crystal diodes (mostly the arithmetic and control sections). A magnetic-drum-type storage is contained in a separate unit.

The necessary input information (both numbers and operational instructions) must be transferred from the magnetic tape of the input section to the electrostatic storage of the storage section before the NAREC may be placed in automatic operation. The magnetic tape reader of the input section senses the magnetized pulses of plus and minus polarity on the tape and transmits corresponding binary indications serially to the arithmetic section. When the arithmetic section has received 45 binary digits (a word), the complete word is transferred to one of the storage locations of the electrostatic storage. All or any part of the 1,024 storage locations of the electrostatic storage may be filled during the input operation.

Words (generally, decimal numbers) may be extracted from the electrostatic storage of the storage section and recorded on magnetic tape as part of the automatic operation of the computer. A word is recorded serially from the arithmetic section, and the recording process is independent of the other computer operations. With the magnetic tape of the recorder moving at 30 inches per second and an anticipated recording rate of 75 pulses per inch, a maximum of 50 45-binary-digit words may be recorded during a 1-second period. The necessary synchronizing and identification pulses are recorded on other channels of the tape.

Digest of paper 50-262, "Design Objectives of the Naval Research Laboratory Electronic Digital Computer," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Not scheduled for publication in AIEE *Transactions*.

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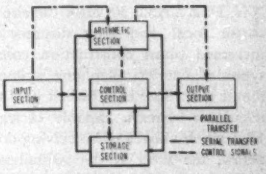
Figure 1. Block diagram of the computer showing paths for transfer of information



An electrostatic storage similar to that developed by Professor F. C. Williams of the University of Manchester (England) provides for the storage of 1,024 words. Any one of these words may be made available to the arithmetic section of the computer in ten microseconds. A magnetic-drum-type storage with a capacity of 2,048 45-binary-digit words serves as a reservoir for the electrostatic storage. Groups of words are received or transmitted to the electrostatic storage as required. For such a function, the magnetic storage need not be capable of receiving or transmitting words at the high speeds provided for in the electrostatic storage.

The arithmetic section, which performs all operations in the binary number system, consists of five registers and a parallel adder. Auxiliary circuits are provided to control the registers and the adder in the performance of subtraction, multiplication, and division. The addition and subtraction operations (including transfers and order interpretation) require 30 microseconds; the multiplication operation 300 microseconds; and division 400 microseconds. The conversion from decimal input data to binary data and from binary data to decimal output data is performed by the computer as a part of the computation.

The series of instructional words (pairs of single-address orders) corresponding to the desired sequence of operations is inserted into the electrostatic storage of the storage section during the input operation. The control section of the computer extracts an instructional word from this storage, interprets it, and activates the circuits in the other sections of the computer involved in the performance of the operation specified. Upon the completion of the two orders of the word, a second word is extracted from the storage section and the interpretation and activation processes repeated. This sequence of word selection and the performance of orders is continued until the sequence of instruction words is completed. Flexibility of coding is provided by orders which alter this strictly sequential process of instructional word selection.

A Medium-Haul Carrier Telephone System

H. H. SMITH

IN THE LAST 30 years the rise of dialing requirements for local and long distance circuits, coupled with increased plant construction costs, has made the older types of carrier telephone systems obsolescent. It was found that there is a distinct field for medium-haul carrier telephone systems, capable of transmitting up to about 12 decibels above, and receiving down to about 15 decibels below, the level at the switchboard at the transmitting end, and providing circuits with 2-wire net circuit losses of two to six decibels. Such a system should transmit voice frequencies from about 300 to 2,700 cycles with a rather flat characteristic. The modulator and demodulator carrier oscillators should be stable to about three cycles to permit use of voice-frequency carrier telegraph systems.

The signaling method should not interrupt the basic carrier channels so that speech-plus-telegraph or signaling may be used. The signaling system should provide a separate signaling path in each direction not interfering with normal functioning of the channel, be immune from false operation by speech currents, and be capable of handling all types of signaling, including ringing, telephone dialing and supervision, railway selector impulses, and other miscellaneous uses, not necessarily related to the speech currents transmitted in the voice-frequency band. The terminating arrangements of both signaling and speech equipment must be sufficiently flexible to be adapted readily to the various types of connecting circuits and line conditions. It should be possible to apply the same equipment to stable broad-band links to obtain twice the number of channels as when applied to wire lines. It is preferable for a medium-haul carrier system to be stackable so that channels may be added as required by traffic growth. By-pass arrangements also must be provided. Maintenance and installation should be possible with relatively simple test equipment, and line-up and maintenance adjustments should be made by controls with graduated scales to permit the technical man to be assisted by helpers with little training. It is important that the equipment be as compact as consistent with convenience of maintenance.

The Federal *9-H-2* medium-haul carrier telephone system was designed to meet these requirements. It provides three stackable channels operating between 3.6 and 35 kc. All of the equipment for each channel is contained on a single panel with over-all front dust cover, the panel being 19 inches wide and $8^3/_4$ inches high. Included with the channel equipment are also the a-c power supply for the channel, the line filter for the lowest channel, and plug-in signaling transmitting and receiving relays. Only one line filter is used for the channel terminals at each end of a system. Relative to one milliwatt test signal applied to the 2-wire drop, the normal sideband transmitting level to line is 12 decibels above one milliwatt, and minimum line receiving level is 18 decibels below one milliwatt. Over-all 2-wire loop gain is about 26 decibels. On a 4-wire drop basis, over-all loop gain is about 43 decibels. The over-all channel transmits voice frequencies from 300 to 2,700 cycles between points of 2-decibel rise, or from 100 to 3,000 cycles between 10-decibel points.

Frequency allocations agree with accepted directional bands between 3 and 30 kc. The suppressed carriers and upper and lower sidebands (USB and LSB) follow:

Channel 1: West—LSB, 7.0 kc; East—USB, 9.0 kc.
Channel 2: East—LSB, 17.0 kc; West—USB, 19.5 kc.
Channel 3: West—USB, 26.0 kc; East—LSB, 35.0 kc.

Two 1-way signaling channels are provided per channel, spaced 3.4 kc away from the suppressed carrier, on the same side as the transmitted sideband. The signaling current is generated at line frequency, not passing through the modulator, and is keyed by a plug-in transmitting relay which may be either an a-c or double-winding d-c type. At the receiving terminal, it is demodulated to 3,400 cycles, is limited and amplified; then it operates a plug-in receiving relay. This relay may be wired to repeat dial impulses or d-c signals or to apply ringing current to the drop, as required by the application. An important feature is dial pulse ratio control in the signal receiving circuit, whereby compensation may be made by turning a control, for external impulse distortion up to about ten per cent in either direction. By this means, distortion inherent in associated trunk equipment up to a reasonable amount may be readily neutralized. For isolated terminal installations serving telephone sets, the power supply equipment can supply both direct current for energizing a common battery telephone and alternating current of mains power frequency to operate the ringer.

The panel has five controls with graduated dials which permit adjusting the combined sideband and signal transmitting level, the combined sideband and signal receiving level, the audio output level to the drop, the sensitivity of the signal receiving circuit, and the dial pulse ratio. Adjustable carrier leak resistors are included in the modulator and demodulator circuits. The relative signal transmitting level may be changed by a soldered tap. Convenient test points in both audio and carrier circuits as well as in d-c signal transmitting and receiving leads are provided by means of inexpensive removable U-links, with pin-jacks fitting standard test lead tips. Using the factory calibrated transmitting level adjustment, a channel may be lined up for operation with only a 1,000-cycle 1-milliwatt oscillator and a rectifier-type meter.

Digest of paper 50-242, "A Medium-Haul Carrier Telephone System," recommended by the AIEE Committee on Wire Communication Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Procedures for Obtaining Registration as a Professional Engineer

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The author presents a review of the procedure involved in becoming a registered engineer and its advantages to the individual and the profession as a whole. A list of national registration boards and boards of engineering examiners is included.

THE LEARNED profession of engineering is as old as history but it was not until modern times that the public, for its own protection, began to require those who sought to practice it to first satisfy certain minimum statutory requirements. The Iroquois Theatre fire in Chicago and other disasters which were manifestations of a more intense civilization served to focus the public eye upon engineering and its responsibilities of life, health, and property. In 1907 the state of Wyoming became the first to adopt an engineering registration or license law. Now all 48 states and three of the territories have such laws.

Since the registration of engineers is for the protection of the community, the public must be the first consideration while the profession and the individuals in it must rank second. The public is interested in protecting itself from the incompetent and the unprincipled ones who seek to prey upon it in the name of engineering. It wants an available supply of dependable engineers. The public is not particularly concerned about providing a better way of life for engineers except as they serve the interests of the people. However, in making engineering a legally regulated profession, engineers were given another opportunity to become a coherent body with unified interests.

Certain considerations characterize the registration laws adopted by almost every state. The most important of them is that only those who have satisfied the requirements prescribed by law may register as professional engineers while the profession has been given the responsibility of saying whether or not applicants have met the requirements. The basic philosophy is essentially that, for the protection of the public, the exclusive right to practice in the field of engineering has been given to those who satisfy the legally prescribed qualification requirements. The profession has the task of determining what the exact requirements are and when they have been satisfied. The value of an ancient and respected custom whereby the qualifications of learned men are judged by others of similar learning who have already established their qualifications is satisfied. Thus, beyond a general outline of what the public requires, the profession is expected to administer itself and is given this right of self-preparation and self-determination. The profession determines what constitutes adequate education and experience and, through board action, authorizes an applicant to practice only when he is considered to be qualified.

Not only does this serve the best interests of the people which should combine us into a body with common interests which are above and beyond the limited responsibilities of technicians.

With the exclusive right to practice engineering also came other important privileges and obligations. An engineer's opinion is the respected judgment of a professional man, accepted as such in court and by the public. The professional engineer has a greater responsibility in the community due to his position of trust in the profession. Heretofore the profession has disowned its birthright of unity. Of the numerous active engineering societies, not one has a membership greater than one-tenth of those who claim to earn their livelihood in engineering. Perhaps by thinking and acting as a single unified profession we can recapture that which we have thrown away. Unless we make an active, organized effort to administer our profession, it will be directed by others through our default.

If the future of our profession lies in this direction and unity is to be achieved by a registered, professional engineering effort, then each of us should make an effort to become registered. Although the steps to be followed are all for the purpose of determining whether or not applicants are qualified to practice, the exact procedure of each state has been developed around the conditions peculiar to it. Obviously Wyoming and its irrigation problems differ greatly from those of the densely populated eastern industrial states such as New Jersey, New York, and Pennsylvania. Just as no two states have identical constitutions, no two registration laws could be expected to be exactly alike. All seek to determine that applicants are adequately mature, of good moral character, properly trained and sufficiently experienced to insure competence in assuming professional obligations and duties.

Registration Procedure. (As the author is affiliated with the New York Board and can speak with authority only in that connection, the following instructions are patterned after the procedure followed in New York state.) In each state there are certain statutory qualification requirements and the application forms are designed around them and arranged to include whatever additional information but it also places an obligation upon those engaged in engineering. Many regard this duty with apathy and fail to realize that professional practice carries with it a special form of citizenship and a preferred position in society,

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each board believes necessary for its considerations. The applicant is required to make affidavit concerning the truth of the statements contained in the completed form. The procedure to be followed is:

1. Obtain the required forms, instructions, and a list of the qualification requirements. Sometimes these are available through engineering society local offices but the board secretary is always in a position to supply them.
2. Execute the application forms according to instructions, being careful to supply all the requested information.
3. Describe experience accurately and concisely so that for each engagement the board will know the title under which you worked, your employer and location, and what you did while so employed. If you want to submit greater detail, do so in a separate, supplemental description.
4. In supplying reference names or endorsements, if required, select those upon whom you can depend to give accurate, dependable replies to the board.
5. Mail to the secretary your completed application, the required fee, and whatever supporting documents are specified in the instructions.

Facts Concerning Application. Usually the name of the applicant is the first required information. This should be your legal name and if there has been a change made by court order so that parts of your training and experience appear under different names, a copy of the court order should be made available to the board.

The question of maturity is left to the judgment of the boards of 27 states and territories, while 13 of them require the applicant to be at least 21 years of age. Another places the minimum at 24 years and ten say he must be at least 25 years old. Thus the date of birth is always asked and often the place, too. Sometimes a board requires this to be verified by a copy of the birth certificate. In 11 states requiring citizenship or a legal declaration of intention to become one, a foreign-born applicant may be required to send in his original papers or those of the parent from which his status is derived. Of the 11, two states accept Canadian as well as United States citizens, seven require citizenship or a legal declaration of intention, while two expect a fully established status. Documents of this nature are irreplaceable and the writer suggests that they be withheld by the applicant until officially instructed to submit them. Then they should either be sent by registered mail or personally taken to the authorities.

Not all qualification requirements are specified in the law of each state or territory. However, good moral character is one which appears in 47 statutes, while the remaining four leave it to the opinion of the board. The methods by which character is established are, in general, by references although these procedures vary considerably among the different boards. All require an affidavit with the application and, in addition, by various methods they obtain statements from the references. Some require reference endorsements by licensed professional engineers. The judgment of professional engineers regarding the character and degree of responsibility is preferred.

Graduation from a recognized engineering course, or the equivalent in training and experience, is required by 48 states. Almost all have examination provisions with varying degrees of board discretion in their usage. Most of them permit the board to accept many years of experience as having demonstrated those qualifications we seek to ascertain by written examinations. However, some go further and require that, in addition, the applicant must show that he has attained recognized standing in the engineering profession if he is to receive favorable consideration because of his long experience. Such provisions are not to be confused with "grandfather clauses" which are those whereby applicants who can successfully show that they have had a prescribed number of years of engineering experience are automatically registered. A grandfather clause is an essential ingredient in the initial phases of registering in a profession and is usually removed from the law after the first few years. Thus, almost none of the current engineering laws retains one that is now effective.

In adopting registration statues most states and territories have felt that an applicant should have practical experience in engineering before he could be expected to practice safely and dependably and, for this reason, have made experience a statutory qualification requirement. This experience must be of a grade and character satisfactory to the board. The acceptability of it may vary between the states. The New York board believes that a graduate can obtain satisfactory experience only in a position or positions for which a technical education is a prerequisite. While few go into positions of responsibility immediately upon graduation, the succeeding years should show a marked advancement towards greater responsibility. Experience descriptions should make clear the applicant's progress.

Examinations. Many states now require applicants to pass written examinations as part of the qualification requirements in engineering. While most boards have the authority to accept many years of outstanding achievement as adequate evidence of qualification, few engineers can afford to wait so long or to gamble that a board will eventually rule that their experience records satisfactorily demonstrate qualification. It is not advisable for engineers to delay for the purpose of avoiding examinations. While the value of examinations as a measure of engineering qualifications is always debatable, they are often the board's only recourse when considering young engineers.

Examinations usually are constructed primarily to test the technical training of the candidate; succeeding questions require the use of engineering judgment and experience must be relied on for satisfactory answers. Many examinations are of the "open book" type but not all of them. In preparing for examinations the candidate should find out their length and scope as well as the circumstances under which they are to be given. Most of us work in rather narrow fields and before taking examinations should do some reviewing in the subjects used less frequently. Refresher courses are offered in many parts of the country to assist in this matter. In addition, it is suggested that the candidate plan his time during the examination to be able to answer enough questions to earn a passing mark.

Almost half of the states have a provision to facilitate the taking of examinations by giving part of them imme-

diately after graduation when technical training is fresh in the minds of graduates. These are called the preliminary examinations and those who pass them become engineers-in-training. After these men accumulate enough satisfactory experience they are eligible to take the remainder of the examinations. The author recommends this procedure to all recent graduates both for its convenience and because of the fact that those taking the examinations in this way are more successful than those who wait until they are eligible to take all of them at once.

An engineer who earns his registration by passing written examinations in one state is in a much stronger position when he seeks a license in another based upon the one he possesses. This kind of a record is much more acceptable to all Boards of Engineering Examiners than any other.

Boards of Registration or Boards of Engineering Examiners are

Alabama: Clifton C. Cobb, Executive Secretary
702 Washington Avenue, Montgomery 5

Alaska: Linn A. Forrest, Secretary
Box 254, Juneau

Arizona: Lewis S. Neeb, Secretary
Post Office Box 1029, Phoenix

Arkansas: V. E. Scott, Secretary
Post Office Box 175, Pulaski Heights Station, Little Rock

California: W. A. White, Executive Secretary
529 Business and Profesions Building, Sacramento 15

Colorado: W. T. Blight, Assistant Secretary
20 Capitol Building, Denver

Connecticut: William K. Simpson, Secretary
30 Oak Street, Hartford 6

Delaware: Thomas J. McDonnell, Secretary
Post Office Box 1266, Wilmington

Florida: Mrs. Ann P. Clover, Executive Secretary
702 John F. Seagle Building, Gainesville

Georgia: R. C. Coleman, Joint Secretary
111 State Capitol, Atlanta

Hawaii: Wm. C. Furer, Assistant Secretary
1909 Aleo Place, Honolulu 14

Idaho: Raymond J. Briggs, Secretary
Briggs Engineer Building, Boise

Illinois: Charles E. Kervin, Superintendent of Registration
Capitol Building, Springfield

Indiana: L. T. Gootee, Executive Secretary
State Capitol, Indianapolis

Iowa: Henry Wichman, Secretary
State Capitol Building, Des Moines

Kansas: H. E. Bullock, Assistant to Secretary
Suite 7, Majestic Building, Topeka

Kentucky: C. S. Crouse, Secretary
University of Kentucky, Lexington 29

Louisiana: F. W. Macdonald, Assistant Secretary
Civil Engineering Building, Tulane University, New Orleans

Maine: Bryant L. Hopkins, Secretary
Bangs Station, Waterville

Maryland: J. W. Gore, Secretary
1101 Key Highway, Baltimore 30

Massachusetts: Albert Haertlein, Secretary
Room 413 C, State House, Boston

Michigan: Henry G. Groehn, Executive Secretary
705 Cadillac Square Building, Detroit 26

Minnesota: Miss Helen D. Carlson, Executive Secretary
316 New York Building, St. Paul

Mississippi: O. B. Curtis, Sr., Secretary
Post Office Box 3, Jackson

Missouri: Mrs. Clemmie V. Wall, Secretary
Box 184, Jefferson City

Montana: Eldon R. Dodge, Secretary
Montana State College, Bozeman

Nebraska: Roy M. Green, Secretary
210 Ferguson Hall, University of Nebraska, Lincoln 8

Nevada: Stanley C. Palmer, Secretary
University of Nevada, Reno

New Hampshire: Ned Spaulding, Secretary
6 School Street, Hudson

New Jersey: Thomas E. Heathcote, Secretary
921 Bergen Avenue, Jersey City 6

New Mexico: John H. Bliss, Secretary
Post Office Box 1079, Santa Fe

New York: Newell L. Freeman, Secretary
23 South Pearl Street, Albany 7

North Carolina: C. L. Mann, Secretary
Room 223, Engineering Laboratories Building,
North Carolina State College, Raleigh

North Dakota: Frank E. Cave, Secretary
State Capitol, Bismarck

Ohio: Robert N. Waid, Secretary
21 West Broad Street, Columbus

Oklahoma: Gwynne B. Hill, Secretary
516 Petroleum Building, Oklahoma City

Oregon: E. A. Buckhorn, Secretary
433 Builders Exchange Building, Portland

Pennsylvania: Miss Rebecca J. Nickles, Secretary
324 Education Building, Harrisburg

Puerto Rico: Luis Cueto Coll, Secretary
Post Office Box 3717, Santurce

Rhode Island: Philip S. Mancini, Secretary
242 State Office Building, Providence

South Carolina: T. Keith Legare, Secretary
Post Office Drawer 1404, Columbia

South Dakota: E. D. Dake, Secretary
School of Mines and Technology, Rapid City

Tennessee: Granbery Jackson, Jr., Secretary
1313 Nashville Trust Building, Nashville 3

Texas: Carl L. Svensen, Secretary
912 Tribune Building, Austin

Utah: Frank E. Lees, Secretary
324 State Capitol Building, Salt Lake City 1

Vermont: Walter D. Emerson, Secretary
Norwich University, Northfield

Virginia: E. H. Williams, Jr., Director
Post Office Box 1-X, Richmond

Washington: Edward C. Dohm, Secretary
Department of Licenses, Olympia

West Virginia: Junius T. Moore, Secretary
301 Morrison Building, Charleston

Wisconsin: W. A. Piper, Secretary
State Capitol, Madison 2

Wyoming: Miss Wilma Hageman, Assistant Secretary
201 State Capitol Building, Cheyenne

Induced Currents in High-Capacity Bus Enclosures

S. C. KILLIAN
MEMBER AIEE

IN RECENT YEARS the air-insulated metal-enclosed high-capacity bus has come into wide use in central stations. These busses are built in a variety of designs with three basic configurations: nonsegregated phase, segregated phase, and isolated phase. They vary mainly in construction between phases. In addition to this, the only outstanding difference is the presence or absence of considerable circulating current in the bus housings.

These circulating currents may be allowed to flow as in the unsegregated- and segregated-phase enclosures where they will heat the enclosure but protect adjacent building steel from inductive and magnetic heating because their field will oppose the field of the main conductor. In the isolated-phase enclosure, where the phase ducts are completely separated from each other, circulating currents cannot flow between phases. The individual phase ducts also are broken into sections by insulating strips which further reduce these currents. Heating in these enclosures will be small but adjacent steel will not be protected from inductive and magnetic heating. Other external means then must be used to keep the temperature of this steel at reasonable values. Where circulating currents are allowed to flow in the enclosure, a careful choice of enclosure material must be made, as this will determine the losses which occur in the enclosure and the voltage drop caused by the main bus.

The induced currents in a nonsegregated- or segregated-phase bus will flow as shown in the simplified diagram of Figure 1. Instantaneous current may be considered to flow in the conductors as shown by the heavy arrows. The currents induced in the top and bottom sheets then will appear (dotted lines) and will flow so as to generate fields whose flux will oppose the field of the main conductor through as much duct length as possible. This then requires the closing of these circuits in the very edges of the sheets as shown by the double dotted lines. This end effect, with its high current concentration, produces a comparatively high temperature rise. Rises in all other parts of the enclosure will be much less.

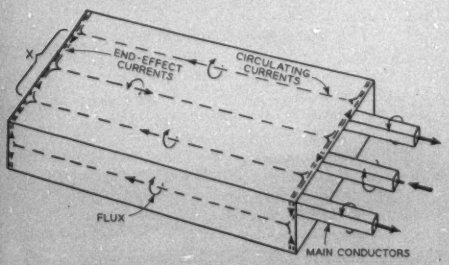

Figure 1. Simplified diagram of induced current flow in enclosure

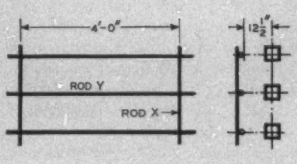

Figure 2. Simple grid used to study the behavior of induced currents

In order to study these circulating currents, their magnitude, distribution, power loss, end effect, proximity effect, their efficiency as counterflux producers, and their effect on temperature rises, many mock ducts were built of rods and special sheets. One simplified grid of five rods was used to represent the top sheet of a duct, see Figure 2. Experiments made on this dummy duct showed that as the rod resistance increased the current decreased. An optimum rod size existed when the diameter of the copper rod was about three-fourths of an inch: at that point the power loss was greatest. This maximum point also was seen when losses occurring in sheets of various material and thicknesses were plotted.

On the basis of the many tests performed and on basic electrical theory, the following conclusions can be made for segregated- and nonsegregated-phase busses:

1. Induced currents in enclosures are proportional to main currents.
2. Decreasing phase spacing of the mains decreases induced currents.
3. Voltages induced are proportional to enclosure length and to the current in the mains.
4. Circulating currents flowing in enclosures reduce the reactances between the main conductors.
5. Circulating currents in enclosures do not increase with the lengthening of the bus after a certain length, say 10 to 20 feet, is exceeded.
6. Large end-effect currents will flow at the end of each enclosure section, and to avoid heating from these currents at every enclosure joint all sections should be electrically bonded together.
7. Proximity effect in enclosures insulated from each other must be considered, since this produces additional heating.
8. On the basis of power loss, an enclosure material can be selected which will provide minimum loss consistent with necessary structural strength and economic requirements.
9. Induced currents in enclosures reduce the field strength outside the enclosure to about ten per cent of that without enclosures.

Digest of paper 50-222, "Induced Currents in High-Capacity Bus Enclosures," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Neutral Inversion of a Single-Potential Transformer

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MANY single-potential transformers are connected line-to-ground on normally grounded circuits that may become an isolated delta by circuit switching (see Figure 1).

Neutral inversion has occurred with this circuit which has resulted in sustained line-to-ground potential of 56 kv on a 34.5-kv insulation class power transformer. The possibility of this phenomenon occuring is increasing with increased use of primary, secondary, and other networks which provide the source for energizing the circuit.

The position of the neutral or ground on a delta circuit is dependent on the phase-to-ground impedances. These impedances to ground consist generally of distributed capacitance, and for the condition of the normally balanced capacitance the neutral will be at the center of the delta. Any application of other impedances on one phase-to-ground will change the impedance balance and will shift the neutral from the center. The voltage across the unbalancing impedance is given by the equation of Figure 1, and for inductive reactance the voltage is plotted as curves 1, 2, and 3 of Figure 2.

The most unstable neutral of a delta circuit is the one with the smallest phase-to-ground capacitance, and is the distributed capacity of the delta winding only. The impedance of the potential transformer without burden is its excitation impedance. This impedance is variable with respect to the voltage and cannot be expressed as an equation, but, by neglecting the harmonics of the excitation current, an impedance curve with respect to the voltage may be plotted from the magnetization curve. The intersection of the impedance curves with the voltage characteristic curves of Figure 2 is the voltage on the potential transformer during an isolated delta condition. When this point is in quadrant 4 the voltage on the potential transformer will be shifted in phase approximately

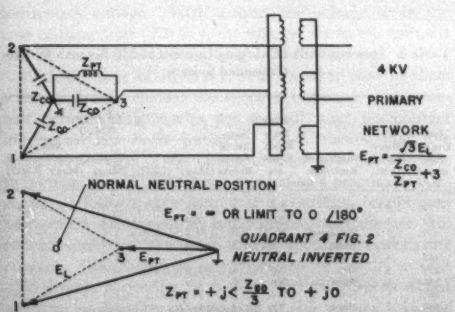

Figure 1. Isolated 3-phase delta with a single line-to-ground potential transformer

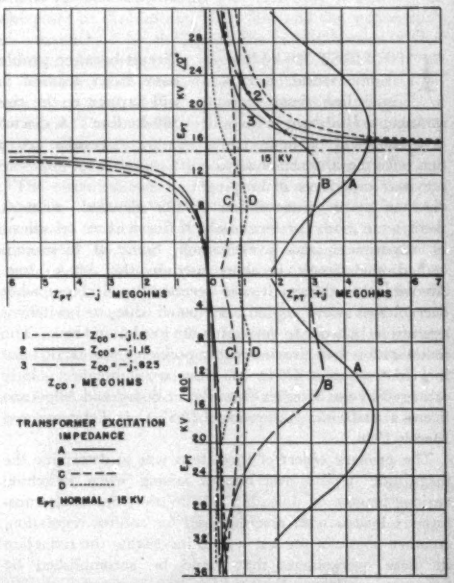

Figure 2. Graphical solution of neutral stability points. No secondary burden

180 degrees or the neutral has inverted about the phase of the potential transformer connection. Without corrective secondary burden, potential transformers *B*, *C*, and *D* all have neutral inversion, but transformer *A* is stable and produces little neutral shift.

The application of a capacitive secondary burden to potential transformers introduces a capacitive impedance in parallel with the normal phase capacitive impedance and potential transformer excitation impedance.

Several tests were made on the equipment used in Figure 2 for which oscillograms of the inversion were made. The tests substantiated the results of Figure 2 both for unburdened and burdened potential transformers.

It is concluded from the work done on this subject that potential transformers purchased for this service must have excitation impedance characteristics equal to transformer *A*, and that capacitor secondary burden can be used with good results on transformers similar to *C*.

Digest of paper 51-14, "Neutral Inversion of a Single-Potential Transformer Connected Line-to-Ground on an Isolated Delta System," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22-26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Field Testing of 220-Kv Air-Blast Circuit Breakers

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Circuit-breaker problems at very high voltages have been studied in Sweden to show what will happen to the circuit breakers on the new 380-kv line. A discussion of the tests and their results are presented here.

THE FIRST 380-kv line[1] in the world, a 593-mile line from Harsprånget to Hallsberg in Sweden, soon will be in operation. In the absence of any previous experience of long-distance power transmission at this elevated voltage, there were many problems which first had to be solved by experiment and investigation. Some of these concerned the circuit breakers used in the 380-kv line. Among other things, it was necessary to find out what overvoltages were to be anticipated due to switching operations in order to determine the insulation level. The investigation into circuit-breaker problems was carried out in field tests on a 220-kv air-blast circuit breaker, jointly arranged by the Swedish State Power Board and Allmänna Svenska Elektriska Aktiebolaget (ASEA) in February and March 1948.

The primary object of these tests was to determine the magnitude of the overvoltages arising when switching various lengths of unloaded transmission line and transformers loaded with reactors used for control regulation. Another object of the test was to investigate the reduction in these overvoltages that could be accomplished by fitting a nonlinear damping resistor across the circuit-breaker gap.

As the 380-kv system is to be carried out with a direct-grounded transformer neutral, the majority of the tests were made with direct-grounded neutral. However, a number of tests also were made with the neutral grounded through an impedance; this was done with regard to the existing 220-kv system which is equipped with Petersen coils.

The circuit breakers in the first stage of the Swedish 380-kv system will be subjected to appreciably greater voltage stresses on each circuit-breaker element when interrupting the line than the 220-kv circuit breaker is, and for this reason many of the tests were carried out with two of the six circuit-breaker elements short-circuited.

These field tests were carried out on a standard 220-kv air-blast circuit breaker of ASEA's manufacture, type designation *HTFY 200/606*, shown in Figure 1.

Uniform voltage distribution across the six circuit-breaker elements is achieved by means of a 300,000-ohm grading resistor, mounted in the circuit-breaker elements. The contact stroke in each element is 25 millimeters, and the contacts are so devised that they reclose a certain time after circuit interruption has taken place. Before reclosing, however, the series-connected isolator opens so that a visible air break is obtained.

All testing was carried out at the Stadsforsen power station, using one of the local 40-megavolt-ampere generators. Owing to the comparatively low generator output the station impedance was rather large so that the line capacitance had a considerable influence on the voltage subsequent to interruption.

DIRECT-GROUNDED SYSTEM

FIGURE 2*A* represents a single-phase line diagram as used in the test circuit, and Figure 2*B* denotes the test circuit breaker which had only four circuit-breaker elements connected in during practically all of these tests. The tests were carried out at a voltage of 220 kv and a frequency of 50 cycles per second, with the exception of the 480-kilometer line, when the frequency was reduced to 40.5 cycles per second. Four lengths of line were investigated, 72, 157, 239, and 480 kilometers. In three of the 33 tests carried out restriking occurred (see Table I).

With an air-blast circuit breaker having a short contact stroke, it usually is possible to interrupt the current as the phase passes through the first zero subsequent to contact separation. The phase displacement is generally close to 90 degrees so that the line will carry direct voltage of the same magnitude as the voltage amplitude prior to interruption. Travelling waves in the line may cause some change in the line voltage immediately after interruption, but their effect is negligible, at least in the case of the line lengths used in this test.

Table I. Interruption of Charging Current at 220 Kv on a Direct-Grounded System

Line Length, Kilometers	Number of Tests	Number of Restrikes	With Nonlinear Resistors	Number of Series Breaks	$k = \frac{\sqrt{3}\,E_{max}}{220\sqrt{2}}$ Bus (Mag)*	Bus (CRO)†	Line (Mag)	Across Circuit Breaker (Mag)	Across Circuit Breaker (CRO)
72	8	None	No	4	1.5	1.7	1.0	1.9	1.5
72	1	One	No	4	2.4		2.4		2.2
72	1	Repeated	No	3	2.2	2.4	2.2		
72	1	None	Yes	3	1.1		1.0		
239	4	None	No	4	1.3		1.0		1.4
239	1	One	No	4	2.0		2.0		2.1
239	5	None	Yes	4	1.2		1.1		1.3
480	5	None	No	4	1.3		1.1		1.5
480	2	None	Yes	4	1.2		1.0		1.3
157	5	None	No	4	1.5		1.0		1.7

*Mag signifies data from magnetic oscillograms.
†CRO signifies data from cathode-ray oscillograms.

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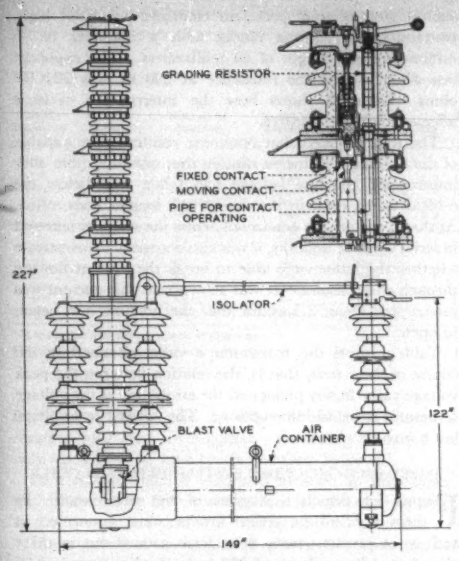

Figure 1. Air-blast circuit breaker used for the test; it has six series-connected power breaks and an isolating switch

The risk of restriking in the circuit breaker depends on the magnitude of the voltage which appears across the contacts subsequent to breaking. This voltage usually reaches its peak value one-half cycle after completed interruption, and represents the sum of the d-c line voltage and the crest value of the bus voltage (see Figure 2). Stations with low power output will have a large station impedance, with the result that the rise in voltage caused by the capacitive charging current will be high, and the longer the power line the greater will be the charging current and also the inductance voltage. The circuit having been broken, the capacitive current disappears, and on the bus there will be a voltage drop corresponding to the earlier inductance voltage. With a fixed line voltage, as in the case of these tests (220 kv), the voltage across the contacts will be lower after interruption if the line is long.

With the type of air-blast circuit breaker used in these tests, maximum contact clearance is obtained about one-half period (at 50 cycles per second) after the contact movement has been initiated, which means that the dielectric strength of the circuit breaker does not continue to increase beyond that point but remains practically constant. It follows, therefore, that if restriking occurs one-half period subsequent to interruption, then the arc will restrike each time the same voltage reoccurs between the contacts. (As flashovers in compressed air usually exhibit considerable scattering, it is more correct to speak about the same probability of restriking at this voltage. In the article it has been assumed, however, that restriking will occur as soon as this voltage is attained.)

Figures 2*C* and *D* show the shape of the voltage waves after restriking. The initial circuit interruption takes place at t_1, when the line is left charged with a voltage which equals the crest value of the phase voltage prior to interruption. The bus voltage drops, owing to the disappearance of the voltage rise in the series inductive reactance. At t_2 the voltage across the circuit breaker attains its maximum value, and restriking is assumed to take place at that instant. The line and the station then are reconnected by the arc in the circuit breaker and a transient oscillation is set up, the frequency of which can be calculated with considerable exactitude from the station inductance and the zero-phase-sequence capacitance of the line. The transient oscillation is superimposed on the system frequency voltage, which returns to the original condition after reconnection of line and station by the arc.

The circuit shown in Figure 2*B* is so chosen that the transient oscillation will have a frequency equal to twice the service frequency. It is assumed that there is a certain amount of damping. Each time a voltage maximum is reached, the transient current passes through zero and consequently conditions are once more favorable for renewed interruption. As the voltage across the circuit breaker at the first of these current zeros will be greater than the restriking voltage E_a, it is nevertheless impossible to effect this interruption. The fact is that just after the current is extinguished, the bus voltage swings back to the generator voltage in a high-frequency oscillation deter-

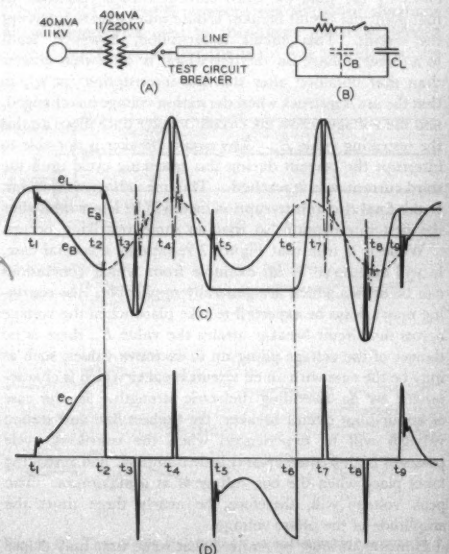

Figure 2. The shape of the voltage waves after restriking. (A). Schematic diagram of the test circuit. (B). Substitute circuit with the line represented by its capacitance. (C). Line voltage e_L and bus voltage e_B. (D). Voltage e_C across the circuit breaker. Restrikes occur at t_2, t_3, t_4, t_5, t_7, and t_8

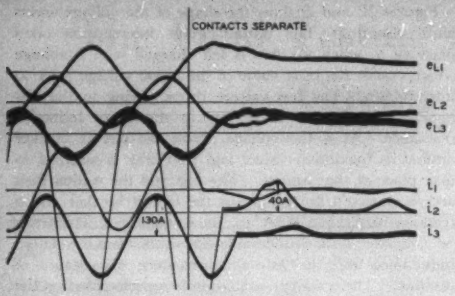

Figure 3. Oscillogram showing interruption of a 480-kilometer line; the circuit breaker is equipped with nonlinear damping resistors; e_{L1}, e_{L2}, and e_{L3} are the line voltages to ground (each 127 kv rms); i_1, i_2, and i_3 are the phase currents. After interruption i_1, i_2, and i_3 show the currents in the resistors. The record of the second phase is magnified

mined by L and C_g, while the line voltage remains at the peak value.

During this transient cycle the voltage across the circuit breaker will be too high to render the attempted interruptions successful, and the circuit can only be effectively broken when the voltage has been reduced sufficiently by damping. In Figure 2 the damping has had the necessary effect by the time the third current zero is reached; at that point the circuit breaker is once more able to interrupt the circuit. This circuit interruption, however, leads to a direct voltage on the line which is somewhat greater than that obtained after the first interruption (at t_1), so that the arc is restruck when the station voltage has changed, and the voltage across the circuit breaker once more attains the restriking value E_a. The circuit breaker is not able to interrupt the current during this restriking cycle until the third current zero is reached. The line voltage subsequent to this final circuit interruption then will be lower than after the first interruption, so that no more restriking occurs.

While it is true that Figure 2 represents a special case, it will still serve as an example from which conclusions can be drawn which are generally applicable. As restriking may always be expected to take place when the voltage across the circuit breaker attains the value E_a, there is no danger of the voltage piling up to excessive values, such as may be the case with an oil circuit breaker which is characterized by an ascending dielectric strength. In the case of an air-blast circuit breaker, the highest line and station voltages will be experienced when the restriking cycle possesses high frequency and little damping, and restriking takes place when the bus voltage is at a maximum. The peak voltage will, therefore, be nearly three times the amplitude of the phase voltage.

However, it must be realized that some time may elapse before definite interruption can take place, and therefore it is naturally preferable if all restriking can be avoided. The danger of restriking may be avoided by connecting in nonlinear resistors across the series breaks, as was done in the course of these tests. The resistors consisted, for each phase, of four porcelain elements 0.5 meter high, containing 29 ceramic blocks with a diameter of 75 millimeters and height of 60 millimeters. The exponent was about 5 and the resistance at 200 kv was 20×10^3 ohms. Figure 3 shows how the interruption cycle is affected by these resistors.

The tests revealed that nonlinear resistors were capable of discharging the line so rapidly that one-half cycle after interruption the line voltage had fallen well below the critical value, even in the case of the longest lines tested. As these resistors are connected across the series breaks and in series with the isolators, it was also necessary to investigate whether the latter were able to break the current flowing through the resistors. It was shown that this current was interrupted about 2.5 cycles after the isolators had begun to open.

Table I gives the maximum k value obtained in the course of these tests, that is, the relation between the peak voltage value in any phase and the amplitude of the voltage to neutral prior to interruption. The highest overvoltage has a k value of 2.4.

IMPEDANCE-GROUNDED SYSTEM (PETERSEN COIL)

FIGURE 5*A* depicts a diagram of the test circuit. In these tests all six series breaks were connected in and, as in previous tests, these were carried out in three phases at a line voltage of 220 kv and a frequency of 50 cycles per second. Certain tests were made with a ground

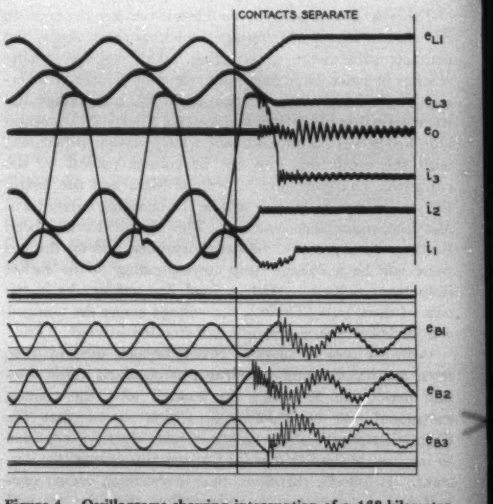

Figure 4. Oscillograms showing interruption of a 138-kilometer line, system neutral grounded with Petersen coil. The line voltages to earth in phases 1 and 3 are e_{L1} and e_{L3} (each 127 kv rms); the voltage across the Petersen coil is e_0 and has the same calibration as e_{L1}. The currents in the three phases are i_1, i_2, and i_3 and are all 52 amperes rms before interruption (the record of i_3 is magnified). The bus voltages e_{B1}, e_{B2}, and e_{B3} are 127 kv rms before interruption

Table II. Interruption of Charging Current at 220 Kv for an Impedance-Grounded System with Six Series Breaks

Line Length, Kilometers	Number of Tests	Number of Restrikes	With Nonlinear Resistors	With Ground Fault	$k = \frac{\sqrt{3}\,E_{max}}{220\sqrt{2}}$ Bus (Mag)*	Bus (CRO)†	Line (Mag)	Across Circuit Breaker (CRO)	Remarks
138	3	No	No	No	2.4	2.1	1.0	2.3	
138	2	No	Yes	No	2.0	1.8	1.0	1.3	Petersen coil 250 amperes overcompensated
138	6	No	No	Yes	3.6	3.2	1.8	3.1	
138	1	Repeated	No	Yes	3.7	3.8	3.1	3.8	
138	1	No	No	Yes	2.8	2.7	1.8	3.0	Petersen coil + resistance
138	2	No	Yes	Yes	2.3	2.3	1.8	1.6	Petersen coil 250 amperes
138	2	No	No	No	2.7	2.6	1.3	1.8	Free neutral
318	3	No	No	No	1.9	1.9	1.0	2.4	
318	2	No	Yes	No	1.7	1.7	1.0	1.3	Petersen coil 279 amperes compensated
318	3	No	No	Yes	2.4	2.4	2.0	2.9	
318	2	No	Yes	Yes	2.4	2.4	1.9	1.6	
318	4	No	No	Yes	2.4	2.4	1.9	3.0	Petersen coil 250 amperes undercompensated
318	2	No	Yes	Yes	2.4	2.4	1.9	1.7	(53 cycles per second frequency)

* Mag signifies data from magnetic oscillograms.

† CRO signifies data from cathode-ray oscillograms.

fault in one phase, and the effect of nonlinear damping resistors also was investigated. Restriking occurred in only one of the 33 tests conducted (see Table II).

In a system which is grounded through an impedance, the voltage across the circuit breaker is influenced by more factors than in the case of a direct-grounded neutral.

Interruption of an unloaded power line with neutral grounded through an impedance is characterized by an oscillation in the neutral point (Figure 4). This oscillation, which naturally affects all three phases, serves partly to increase the overvoltage at the instant of interruption, and also serves to raise the voltage one-half period after interruption, when the risk for restriking is greatest. Most severely affected is the phase to be extinguished first, as the voltage across the circuit breaker in this phase at the instant of extinguishing the final phase will be close to the normal amplitude value, and the neutral point oscillation will have been only slightly damped before the voltage maximum is reached.

Figure 5*B* shows voltage waves obtained from the test circuit of Figure 5*A*. In phases 1 and 3 restriking has occurred almost simultaneously. Restriking occurs in phase 3 because the arc restriking in phase 1 causes a voltage surge with a magnitude equal to the voltage across the circuit breaker in phase 1 at the instant of restriking. This surge travels into the transformer and sets up an oscillation with great amplitude in the neutral point. This oscillation also influences the voltage of the other two phases. The voltage in phase 3 becomes excessive, and the arc restrikes in this phase. The appearance of this oscillation in the two phases when a restrike occurs only in one phase is shown in Figure 5*C*. In this case the voltage across the circuit breaker just before restriking is only 350 kv (some of the circuit-breaker elements were not in function), but the voltage to earth in phase 2 becomes as high as 600 kv. This indicates that a restrike in one phase of an impedance-grounded system may cause dangerously high overvoltages on the supplying transformer.

As in the previous tests, the damping resistors materially lower the overvoltages, and, by discharging the line, reduce the voltage one-half period after interruption to values which are safely below the restriking voltage. The current flowing at the instant of opening the isolators was less than 10 amperes maximum in all the tests, and the arcing time of the isolators was the same as for the direct-grounded system. Results of the tests are given in Table II. The highest overvoltage has a k value of 3.8 and is obtained with the 138-kilometer line and with a ground fault in one phase; the only restriking occurred in this test. With nonlinear resistor the highest overvoltage has a k value of 2.4.

INTERRUPTION OF SHUNT REACTOR LOAD

FIGURES 6*A*, *B*, and *C* represent the simplified diagrams of connections used to investigate different service conditions. Protection for the plant was provided in the

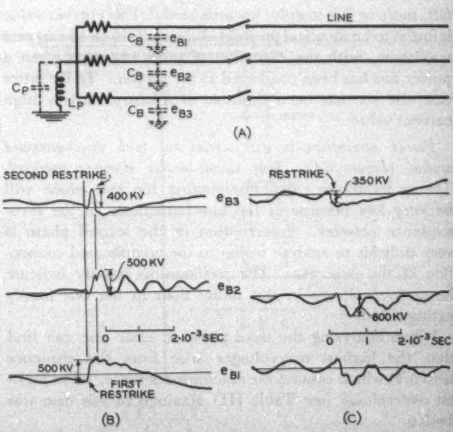

Figure 5. Test of the bus voltage when restriking occurs in a 138-kilometer line with the system neutral grounded with a Petersen coil. (A). Test circuit; phase 2 was grounded on the line side of the circuit breaker. (B). Cathode-ray oscillogram showing a restrike in phase 1 and almost simultaneously a restrike in phase 3. (C). Restrike in phase 3 and oscillations with high amplitude in the other two phases

Table III. Interruption of Reactor Current at 220 Kv

Inductance on Reactor Side, Henrys	Number of Tests	Number of Series Breaks	With Nonlinear Resistors	Reactor Current, Amperes	$K=\frac{\sqrt{3}E_{max}}{220\sqrt{3}}$ Bus (Mag)*	Reactor Side (Mag)	Reactor Side (CRO)†	Across Circuit Breaker (CRO)	Remarks
16.8	8	4	No	23	2.2	2.6	2.6	2.7	Connection Figure 6A
6.0	4	4	No	63	1.5	1.9	1.8	2.5	
16.8	2	4	Yes	23	1.0	1.8	1.8	1.0	Connection Figure 6A
6.0	2	4	Yes	64	1.1	1.7	1.7	1.1	
16.8	2	4	No	23	1.0	3.9‡		3.3	Connection Figure 6B
16.8	2	4	Yes	23	1.0	2.0	2.0	1.0	
16.8	2	6	No	25	1.0	3.2	3.4‡	4.5	Connection Figure 6C
16.8	1	6	Yes	25	1.0	1.9		1.0	

* Mag signifies data from magnetic oscillograms.

† CRO signifies data from cathode-ray oscillograms.

‡ Flashover in rod gap.

form of rod gaps, set to 630 kv, and connected on the reactor and station side. For these tests, which were carried out at about 220 kv, two values of shunt reactor inductance were employed, which when translated to the high-voltage side represented 16.8 and 6.0 henrys. These reactor values and the station inductance give currents of 24 and 65 amperes rms. Interruption of the heavier current did not produce any serious overvoltages, which is explained partly by the fact that the forced interruption does not result in an abrupt cutting off, and partly by the lower inductance which signifies a correspondingly lower energy content at the instant of forcing.

From the oscillograms it is possible to determine the current values at which forced interruption takes place, that is to say, the current value at which the current begins to depart from the sinusoidal shape and commences to fall, more or less steeply, towards zero. This current value is found to be identical for most of the tests, 10 to 15 amperes maximum, with the exception of those instances when a power line has been connected to the station. In the latter case the arc has been unstable at a comparatively high current value.

Forced interruption in tests carried out with direct-grounded neutral (Figure 6A). Four circuit-breaker elements employed. The overvoltages when interrupting the first phase will be very low because of the low inductance in the zero-sequence network. Interruption in the second phase is very difficult to analyze owing to the complicated connection of the networks. The oscillograms usually indicate lower overvoltages in this phase than in the one finally extinguished.

When analyzing the third phase to clear one can find that the highest overvoltages arise from the sequence networks which contain the reactor inductance. The highest overvoltage (see Table III) obtained in this case was $k=2.6$.

Forced interruption in tests with direct-grounded neutral and a 40-kilometer line connected to the bus (Figure 6B). Four circuit-breaker elements employed. Owing to the small inductance of the zero-sequence network in the first phase to clear, the overvoltages produced at forced interruption will be low as in the previous case.

When interruption takes place in the third phase the capacitances of the station and reactor sides are connected across the arc, and when there is no line connected to the bus the two capacitances will be about equal. When a line is connected to the bus, the capacitance of the latter increases to several times that of the reactor side, and the resultant capacitance in parallel with the arc will be greater than in the first case. Increased parallel capacitance across the arc facilitates forced interruption and serves to make the arc unstable at high current values.

The oscillogram in Figure 7 (bus side) indicates that an attempt at forced interruption has occurred in the third phase to clear, but that the current did not at first fall to

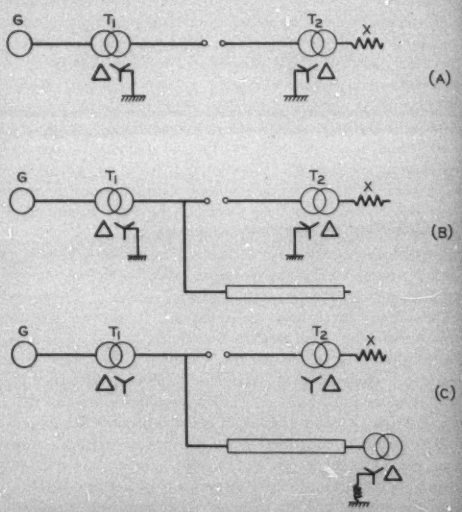

Figure 6. Connections at the shunt reactor tests. Generator G rated 40 megavolt-amperes, 11 kv; transformer T_1 rated 40 megavolt-amperes, 11/220 kv; transformer T_2 rated 60 megavolt-amperes, 11/220 kv; reactor X rated 10 and 30 megavolt-amperes. (A). The neutrals of T_1 and T_2 grounded. (B). 40-kilometer line connected to the bus. (C). 138-kilometer line connected to the bus; the neutrals of T_1 and T_2 isolated

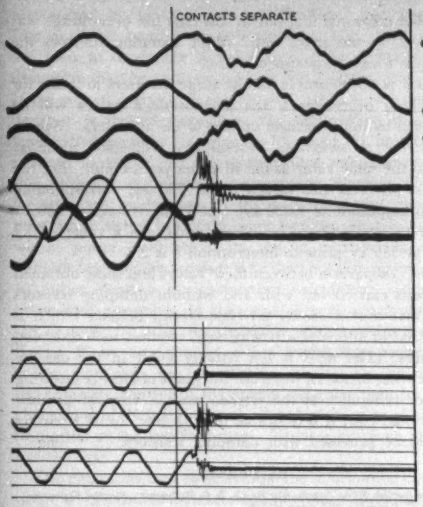

Figure 7. Oscillograms showing interruption of reactor load (test connection Figure 6A); e_{B1}, e_{B2}, and e_{B3} are the bus voltages to ground (120 kv rms before interruption); i_1, i_2, and i_3 are the reactor currents (23 amperes rms). The direct current i_3 depends on a flashover in the protection gap. The reactor voltages are e_{R1}, e_{R2}, and e_{R3}

zero. It was only after several attempts had been made that the current went down to zero, and then it was accompanied by overvoltages so high that an arc was struck across the protecting gap, thereby effectively discharging the magnetic energy stored on the reactor side.

From the test results in Table III it appears that the largest k value is 3.5, but this value is limited by the protection gaps.

Forced interruption in tests carried out with free neutral (capacitor connected to neutral) and with a 138-kilometer line connected to the station (Figure 6C). Six circuit-breaker elements employed. The tests were carried out with isolated neutral in both transformers and with a power line connected to the station, the latter being connected to another transformer at the other end with a neutral grounded via a Petersen coil. Both transformer neutrals were equipped with overvoltage protection consisting of an 18,000-micromicrofarad capacitor on the reactor side. In this case also the first phase to clear will give rise to high overvoltages, as the zero-sequence network will have a considerable impedance.

Because of the large capacitances connected in parallel with the arc, forced interruption can be carried out at comparatively heavy current, as in the previous case. On the reactor side the voltage is usually not limited by the dielectric strength of the circuit breaker, as the maximum voltage on the reactor side occurs at the first peak of the oscillation, whereas the maximum voltage stress on the circuit breaker occurs at the second peak. Therefore, it is quite possible for flashover to take place on the reactor side without the strength of the circuit breaker having been exceeded.

In this case the largest k value is 3.4 for the reactor side and 4.5 across the circuit breaker (see Table III). As in the previous case, the overvoltages on the reactor side are limited by the protection gaps.

The damping resistors serve materially to reduce the overvoltages in these tests also. Table III shows that the maximum k value is reduced to 2.0. The arcing time of the isolators in the tests with direct-grounded neutral was about the same as in the former tests. In the tests with free neutral the arcing time of the isolators was a little longer, but no difficulty was experienced in interrupting the resistor current.

RESULTS APPLIED TO THE 380-KV NETWORK

THE TESTS carried out with a direct-neutral were so devised that the results should be applicable to the 380-kv system. However, they will also be useful in the solving of the problems arising in connection with the Swedish 220-kv system, which is at present grounded through Petersen coils, but which will be direct-grounded in the near future.

Figure 8 shows the wiring diagram of the single-power-line 380-kv system in the first stage of completion. In this stage there will be the most difficult case of circuit breaking with an off-load power line. As described in a report of the International Conference on Large Electric High-Tension Systems,[2] there will be a powerful rise in

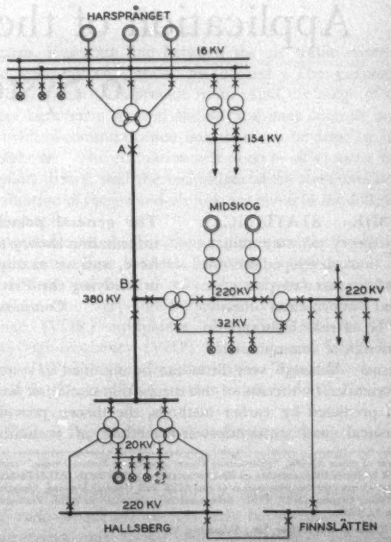

Figure 8. Line diagram showing the first stage of the Swedish 380-kv system

voltage in the first moment after a tripping of circuit breaker *B*, when the Harsprånget generators are running at full load. With one of the Harsprånget generators in operation and at a line voltage of 370 kv, the line will be subjected to a voltage of 585 kv at Harsprånget and 670 kv at Midskog subsequent to circuit breaker *B* tripping. If circuit breaker *A* is required to trip after *B* but before the automatic generator regulation has had time to take effect, it will be a rather severe case of breaking, as the voltage at circuit breaker *A* prior to interruption is 155 per cent of the service voltage. The purpose of these tests has been to simulate these conditions and similar cases of excessive voltages across the power breaks by reducing the number of breaks employed in the test.

The highest overvoltage factor experienced on the bus side of the circuit breaker was 2.4 with restriking and 1.3 without restriking for the longest line and 1.7 for the shortest line. These are the values obtained without the use of damping resistors. With damping resistors k was 1.2 for all line lengths. With a k value of 2.4, restriking in this case would produce an overvoltage having a peak voltage of 1,150 kv.

The interruption tests with reactor-loaded transformers have shown that in this case even higher overvoltages may arise, especially if an unloaded line is connected to the bus side of the circuit breaker. Without damping resistors the k value measured 3.5, but in this case the overvoltage was limited by the spark gap. With damping resistors the highest k value amounted to 2.0.

As it is not desirable for the surge diverters to ignite for switching overvoltages, the permissible k values will be decided by the sparkover voltage of the diverters. Sparkover due to switching overvoltages will take place at about the same value as for 50 cycles per second. For the 380-kv diverter this means about 720 kv, corresponding to an amplitude of 1,020 kv. At a line voltage of 380 kv prior to interruption this corresponds to a k value of 3.3 and at 585 kv prior to interruption k is 2.2.

The comparison between these values and those obtained for tests carried out with and without damping resistors indicates that a 380-kv air-blast circuit breaker which is required to interrupt a reactor load requires such damping resistors. The need is not equally great in the case of line circuit breakers, but from the point of view of ensuring service reliability of the system, and in view of the low additional cost, it is desirable that all line circuit breakers should be provided with damping resistors.

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Application of the Information Theory to System Design

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The general principles of the application of information theory to system design is discussed here, and an example is given showing its use in studying the Private Line Air Traffic Control Communication System.

THE STATISTICAL theory of communications, developed over the past few years and quite often called information theory, can be of real assistance in the design of communication systems. Although very little can be obtained in system performance by the use of this theory that could not have been predicted by earlier methods, the theory provides a logical and straightforward method of evaluating a communications problem and tells directly the effect of necessary compromises from the ideal in bandwidth, power, rate of transmission of information, and so forth. In this article a short general discussion of the method will be followed by a practical example of a communication system that has been designed in accordance with the method. This is the interim "Private Line" communication link between the airport traffic controller and the aircraft which is under his surveillance.

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Although the author served on Special Committee 47 of the Radio Technical Committee for Aeronautics, the material in this article is primarily the work of a large group on this committee; members of the committee are too numerous to name individually. The evaluation was a group effort under the guidance of Vernon C. Weihe.

DESIGN PRINCIPLES

A PRELIMINARY STATEMENT of the method of system design is deceptively simple. One merely computes the maximum rate at which information must be

transmitted in units of bits or Hartleys* per second. The available bandwidth and carrier-to-noise ratio then are used to determine the maximum rate at which information may be transmitted over the facilities available. If the second quantity is greater than the first, the system designer is indeed fortunate; the information may be transmitted over the transmission link, and the problem is reduced to one of inserting a controlled redundancy into the message to improve transmission clarity. If the facilities are inadequate to the task, then the designer must strive either to obtain more facilities, that is, bandwidth, power, and sensitivity, or he must wring some redundancy from his message if he does not give up entirely. In either event a straightforward calculation yields an immediate answer as to the possibility of accomplishing the desired task with the available equipment and spectrum. If, by any chance, either transmitter power, receiver sensitivity, or transmission bandwidth are under the complete control of the system designer, then he may choose one of these in order to allow transmission of his information at the required rate. Usually, however, this is not the case.

The equations used to determine the information content of the set of possible messages and the information handling capacity of the system are well known[1,2] but they will be repeated here for completeness.

To find the information content of the set of messages that may be transmitted one uses the expression

$$H_1' = n' \log_{10} s \tag{1}$$

H_1' is the rate of information output of the message source in Hartleys per second where s is the number of possible equally likely significant values (the case where the values are not equally probable is taken up by Dr. Shannon,[1] but is of practical use only when complex coding is permissible) which the message may have at any given time, and n is the number of times per second a value must be chosen in order not to lose information. If the message is in the form of an electric signal, and has no redundancy, that is, its future may not be guessed with significant accuracy from *a priori* knowledge or from the past history of the message, we have

$$s = 1 + S/N \tag{2}$$

where S/N is the signal-to-error (noise) ratio at the input to the modulator in the generalized communication system shown in Figure 1. S/N must also be the signal-to-error (noise) ratio at the output of the demodulator in this system if no information is to be lost.

Said in another way, from the viewpoint of the information source, s is the number of symbols that could have been emitted at any instant of time. Of this ensemble, one will be emitted n' times per second. This relation defines n' in equation 1.

In electrical terms we have

$$n' = 2f_e \tag{3}$$

where f_e is the premodulation and post demodulation bandwidth of the system shown in Figure 1. The coder and decoder of Figure 1 may be used to remove and/or insert redundancy into the message as desired.

To determine if facilities are adequate for the information source the following equation is used:

$$H_2' = 2B \log_{10}(1 + C/N) \tag{4}$$

Here H_2' is the information handling capacity of the transmission link, B is the bandwidth of the elements between modulator and demodulator, and C/N the carrier-to-noise ratio at the input to the demodulator.

If H_2' is greater than H_1' the system is adequate to handle the demands of the source of information. If not, as has been mentioned, something must be done to either the information or the communication equipment.

APPLICATION TO AIR TRAFFIC CONTROL

To go to a practical example, Special Committee *41* of the Radio Technical Committee for Aeronautics had as its task an operational and technical evaluation of a Transition Period Air Traffic Control Communication System, a private line between the air traffic controller and each aircraft under his control. The purpose of such a system is to provide more rapid exchange of messages between a ground station and each aircraft on an individual communication link than can be done by radio telephone. The evaluation was done by *SC41* using information theory, and the techniques which were used in the evaluation of the ground-air link are given in the following paragraphs.

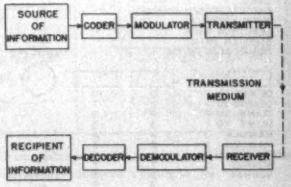

Figure 1. A block diagram of generalized communications systems

Available for this communication system is the band of audio frequencies between 5,000 and 7,000 cycles. This band lies between the voice channel and the subcarrier used in the very-high-frequency omnidirectional radio range (VOR) equipment. It is available on VOR, very-high-frequency (VHF) localizers, and VHF Tower and VHF Enroute Communication Transmitters. This band is also available in the standard VHF Navigation Receiver.

Thus, if this audio band could be used, no new radio equipment would have to be added on the aircraft or on the ground to perform the private line function. Only terminal equipment would be required. Inasmuch as the radio-frequency carriers may be modulated by other subcarriers, only 15-per cent modulation is available for private lines. This means the system must operate well with a minimum carrier-to-noise ratio.

* Bit is defined as a unit of information capacity, equal to one binary decision, or the designation of one of two possible values or states of anything used to store or convey information. Hartley is defined as a unit of information capacity, equal to one decimal decision, or the designation of one of ten possible values or states of anything used to store or convey information.

Substituting bandwidth and minimum carrier-to-noise ratio in equation 4

$$H_3' = (2)(2000)\log(1+1) \quad (5)$$

Since C/N must be assumed a minimum of unity (actually rms carrier-to-noise ratio must be eight decibels to obtain a peak carrier-to-noise ratio of unity) it is convenient to take H_3' in bits per second and use a logarithm to the base 2. This gives

$$H_3' = 4000 \text{ bits per second} \quad (6)$$

as the capacity of the equipment. The remainder of the system design comprised an attempt to force the information source to fit this mold. By the use of visual presentation to the pilot and automatic or key-punch message selection, a predetermined group of messages may be used and one chosen and presented efficiently.

As a result of considerable work by the operational group, the messages to be presented, and their display,

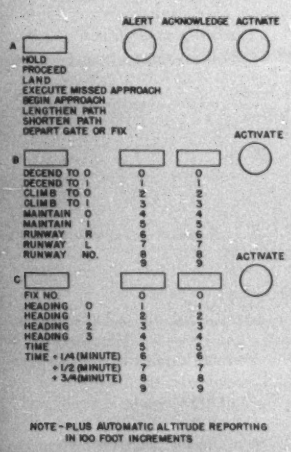

Figure 2. Information to be presented by cockpit display

were chosen as shown in Figure 2. In this figure the possible messages that may appear in each position are shown in tabular form beneath the rectangle depicting the slot through which the message appears. Circles indicate buttons to be pressed by the pilot to tell the controller that he is acting on instructions (corresponding to "Wilco").

From Figure 2 it may be seen that a complete ground-to-air message comprises seven "words" and that each word has a maximum of ten possible choices or values. This sets s in equation 1 as ten. Since transmission must be in binary code to operate at minimum carrier-to-noise ratio, s was fixed at 16, the nearest larger power of two, or 2^4, with a resultant possibility of an increased number of messages or a safety code (one employing redundancy) should it be desired. From Figure 2 we also obtain n as seven words per unit of time in which an aircraft must be contacted.

Operationally it was determined that each of at least 15 aircraft should be contacted every five seconds, and that at least 60 assignable aircraft identities should be available. The aircraft identity, which makes the private line private, therefore requires two more words.

Summing up, nine words per aircraft must be transmitted in 5/15 or 1/3 second. This means a rate of 27 words per second. Each word has a content of four bits, since 16 choices are available. The information handling capacity required of the system is therefore 108 bits per second.

Comparing the required capacity of 108 bits per second with the available capacity of 4,000 bits per second, we see that ample system information handling capacity is available. Since equation 4 is based on the use of ideal filters, a conservative design would only attempt to obtain 2,000 bits per second.

USE OF EXCESS CHANNEL CAPACITY

Since the available channel capacity is so much greater than required, it was recommended that controlled redundancy be introduced in the form of a self-checking code. If a word is sent once in the marks and once in the spaces of a code group, it is immediately apparent if an error has been made. This safety coding requires a capacity of 162 bits per second. The additional capacity still available may be used to obtain improved operation at low carrier-to-noise ratios or to contact more aircraft per second. In practice, some capacity must also be used up in this particular system to allow for transmission lag through the link and to allow for a "Screen Lift" signal, not previously mentioned, that assures the pilot his instructions have been checked on the ground, after retransmission from plane to ground, and found accurate. Inasmuch as the private line is to be operated in conjunction with the phase- and interference-sensitive VOR circuits, it was thought that the remaining additional capacity would best be used in protecting these circuits and in obtaining improved performance at low signal levels.

RESULTS OF ANALYSIS

The preliminary analysis given in the foregoing ensured that a conservative system design could be obtained, and that the necessary equipment design would be a straightforward problem. From this analysis it was possible to proceed with confidence to a consideration of specific equipment.

The example given illustrates certain basic principles worthy of special note. These are the calculation of system information handling capacity and information source output, the use of a coding scheme exactly fitted to the limited information which is to be transmitted, and controlled redundancy in order to obtain improved system reliability.

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Loci of Complex Impedance and Admittance Functions

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CURVES OF impedance and admittance in the complex plane for various combinations of 2-terminal 3-element linear dissipative networks are extremely useful in the solution of many electrical engineering problems because of the direct, straightforward manner in which they show graphically the resistive and reactive components of complex impedance and admittance, the magnitude of impedance and admittance, and the phase shift at all frequencies between zero and infinity. The curves also reveal that the 16 possible combinations of 2-terminal 3-element networks fall into four main groups of four networks each.

One of the main groups of four networks is shown in Figure 1. In each of the four plots of Figure 1, the real and imaginary components of complex impedance in normalized form are plotted along the real and imaginary axes of the complex impedance plane. A nonuniformly distributed scale of normalized frequency F/F_0 exists along the K curves of each plot. In the cases where K curves appear in their entirety, the entire range of frequencies is covered, from zero to infinity. From the information given about F/F_0 and K for each network, it is readily apparent that the impedance of each network may be found graphically at any frequency in either complex or polar form.

Important concepts involving relationships among the four networks of each group are those of inverse, reciprocal, and equivalent networks. The first important concept is that of inverse networks. Two networks with impedances Z_1 and Z_2 are each the inverse of the other with respect to a real constant R if:

1. The impedances satisfy the relation $Z_1Z_2=R^2$.
2. Corresponding elements are related by $L/C=R^2$.
3. Elements in series in the given network appear as inverse elements in parallel in the inverse network, and vice versa.

The second concept deals with reciprocal networks. Two networks are the reciprocal of each other if:

1. The impedance of one is the conjugate of the impedance of the other.
2. The normalized frequency of one is the reciprocal of that of the other.
3. Corresponding elements are related by $L/C=R^2$.
4. Elements in series in the given network appear as inverse elements located also in series in the reciprocal network, and similarly for elements in parallel.

The third concept, which does not apply to the group of networks in Figure 1 but does apply to other groups, concerns equivalent networks. Two networks are equivalent if:

1. The impedance of one is equal to the impedance of the other at corresponding frequencies.
2. Elements in series in the given network appear as elements of the same type in parallel in the equivalent network, and vice versa.

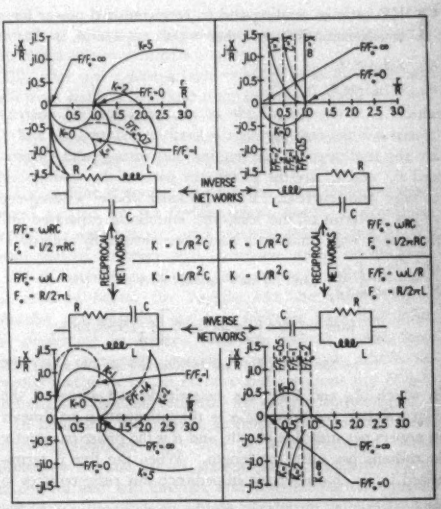

Figure 1. Normalized complex impedance curves for one group of 2-terminal 3-element networks

In one application a wide-band amplifier was designed to have a variation in gain from the mid-band value of less than 0.2 decibel and a phase shift of less than 25 degrees between 5 cycles and 4.5 megacycles. A high- and low-frequency compensation network was designed with the use of these types of curves.

The curves of normalized impedance and admittance plotted in the complex plane for 2-terminal 3-element networks are particularly useful because of the wealth of information they contain. Network behavior is shown more completely and directly than by any other type of plot. The curves are especially useful in determining the most useful frequencies for accurate calculations and in readily showing the frequency ranges in which the effects of certain elements may be neglected.

The number of possible applications is unlimited. As familiarity with the curves is gained many specific applications suggest themselves.

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Calculating Transmission-Line Load Impedance

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THE ratio of sending-end to receiving-end power for a transmission line, or other 4-pole apparatus, is

$$\frac{W_s}{W_r}=\frac{E_sI_s+E_s'I_s'}{I_r^2|\mathcal{Z}|\cos\phi} \tag{1}$$

where I_r is the magnitude of the receiving-end current, $|\mathcal{Z}|\cos\phi$ is the real part of the load impedance, E_s and I_s are the real parts of the sending-end voltage and current, and E_s' and I_s' are the imaginary parts of the sending-end voltage and current. By expressing these sending-end values in terms of the long-line equations, expanded into their real and imaginary parts, one eventually obtains

$$\frac{W_s}{W_r}=\frac{1}{2\cos\phi}\left[\frac{|\mathcal{Z}_0|}{|\mathcal{Z}|}(\sinh 2\alpha l\cos\theta-\sin 2\beta l\sin\theta)+\frac{|\mathcal{Z}|}{|\mathcal{Z}_0|}(\sinh 2\alpha l\cos\theta+\sin 2\beta l\sin\theta)\right]+\frac{1}{2}[(\cosh 2\alpha l+\cos 2\beta l)+(\cosh 2\alpha l-\cos 2\beta l)(\cos 2\theta+\sin 2\theta\tan\phi)] \tag{2}$$

in which $|\mathcal{Z}_0|$ and θ are the magnitude and phase of the characteristic impedance, α is the attenuation parameter in nepers per unit line length, and β is the phase parameter in radians per unit line length. When the line is terminated in its characteristic impedance this ratio reduces to

$$\left.\frac{W_s}{W_r}\right|_{z=z_0}=\epsilon^{2\alpha l} \tag{3}$$

which is not necessarily the lowest power ratio obtainable but which serves as a simple and useful reference.

Differentiating equation 2 with respect to $|\mathcal{Z}/\mathcal{Z}_0|$, equating to zero and solving, leads to

$$\frac{|\mathcal{Z}|}{|\mathcal{Z}_0|}=\sqrt{\frac{\sinh 2\alpha l\cos\theta-\sin 2\beta l\sin\theta}{\sinh 2\alpha l\cos\theta+\sin 2\beta l\sin\theta}} \tag{4}$$

Since this relation is independent of the load impedance angle ϕ, it represents the best load impedance magnitude ratio irrespective of ϕ. This ratio reduces to unity for line lengths which are multiples of a quarter wave length, at which $\sin 2\beta l=0$, and approaches unity for such large attenuations that $\sinh 2\alpha l$ becomes much larger than unity. This impedance ratio will be unity for all line lengths if θ, the angle of the characteristic impedance, is zero. The characteristic impedance of most common lines has a negative angle, approaching -45 degrees for cables with negligible inductance and leakage conductance. For such lines the impedance magnitude ratio will be greater than unity for lines of less than a quarter wave length, less than unity lengths between a quarter and half wave length, then alternately greater and less in succeeding regions, becoming negligible as the attenuation increases with length.

Differentiating equation 2 with respect to ϕ, equating to zero, and solving, leads to

$$\phi=\sin^{-1}\frac{\sin 2\theta(\cos 2\beta l-\cosh 2\alpha l)}{\frac{|\mathcal{Z}_0|}{|\mathcal{Z}|}(\sinh 2\alpha l\cos\theta-\sin 2\beta l\sin\theta)+\frac{|\mathcal{Z}|}{|\mathcal{Z}_0|}\times(\sinh 2\alpha l\cos\theta+\sin 2\beta l\sin\theta)} \tag{5}$$

If differentiated again with respect to the impedance magnitude ratio, this again leads to the best ratio given by equation 4. Some additional simplification is gained by substituting this ratio in equation 5, which then becomes

$$\phi|_{\phi_{max}}=\sin^{-1}\frac{\sin 2\theta(\cos 2\beta l-\cosh 2\alpha l)}{2\sqrt{(\sinh 2\alpha l\cos\theta)^2-(\sin 2\beta l\sin\theta)^2}} \tag{6}$$

Here, because of the $\sin 2\theta$ factor, ϕ will be zero when θ is zero, so the characteristic impedance must be the most efficient load whenever it is a pure resistance. When θ is not zero the sign of ϕ should be opposite to that of θ, but not necessarily its exact negative unless the attenuation is very large, in which case the most efficient load will be the conjugate of the characteristic impedance.

Figure 1 shows the impedance magnitude ratio and load impedance angle for maximum efficiency plotted as a function of length for a 19-gauge nonloaded telephone cable operating at a frequency of 1,000 cycles. For such a cable, $\mathcal{Z}_0=470.1/-42.8$ degrees, $\alpha+j\beta=0.1249+j0.1338$, and the wave length is 46.95 miles. In this case, θ is so near its limiting value of -45 degrees that the best load becomes radically different from the characteristic impedance for short lines. However, the attenuation is so high that, beyond a quarter wave length, the best load is the conjugate of the characteristic impedance.

Application of this analysis may be quite limited as power transmission engineers are concerned primarily with electrically short lines which can be studied by simpler methods based on approximately equivalent networks.

Figure 1. Impedance magnitude ratio and load impedance angle as a function of length

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Control of Gas Turbines for Power Generation

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THE DEVELOPMENT of the combustion gas turbine as a new type of prime mover for power generation has required the parallel development of suitable controls. The control being used at present on General Electric gas turbines provides for semiautomatic starting and stopping of the unit for speed and load control and for protection of the unit under abnormal conditions.

Several characteristics of gas turbines make the control problem different from that encountered with other types of prime movers. For instance, gas turbines are not self-starting and are not self-sustaining below about 50-per cent speed. Therefore a means must be provided to crank the unit to firing speed and to assist acceleration after firing. A temperature control must be provided to limit maximum and rate of change of turbine inlet temperature to prevent damage to the turbine. Turbines that normally operate on Bunker-*C* oil must be started on Diesel oil and transferred to Bunker *C* at or above idle speed.

These unique characteristics of the gas turbine made it desirable to provide partial automatic control on the first commercial gas turbine. Later designs, evolved from the first control, are more automatic and include changes to improve reliability, to prevent damage by operational errors, and provide more protection for the gas turbine.

The first application of the automatic control has been to a 3,500-kw oil-fired unit. The same basic control can be applied to other turbines and natural-gas-fired units.

The following components are mounted on the turbine:

1. A unit-driven variable-displacement pump to obtain the required range of fuel flow for speed and load control. The displacement of the pump is set by a control oil pressure from the fuel regulator.
2. Fuel regulator and electric governor, an electro-hydraulic servomechanism into which are fed a speed signal, an adjustable fuel limit, and an exhaust temperature signal. Output of the regulator is a control oil pressure in accordance with whichever of the signals requires the least fuel flow. The speed signal is obtained from a shaft-driven tachometer generator. Speed is adjustable over a 2-to-1 range by a motor-driven speed-setting rheostat. The adjustable fuel limit sets the control oil pressure for starting and acceleration. The exhaust temperature signal is obtained from a gas-filled bellows on the turbine exhaust hood.
3. Solenoid-operated stop valve in the fuel inlet line.
4. Overspeed governor set to shut the unit down at 110-per cent speed.
5. Motor-operated fuel transfer valve.
6. Flame detectors.
7. Ignition system to initiate combustion.
8. Atomizing air compressor for fuel atomization.
9. Lubricating oil pumps. A shaft-driven pump backed up by an a-c motor-driven auxiliary pump and a d-c motor-driven emergency pump.
10. An a-c motor-driven turning gear to start the unit from rest and a wound-rotor induction motor to crank the unit to self-sustaining speed.
11. Miscellaneous pressure and temperature switches in the lubricating oil, fuel oil, and atomizing air systems.

The turbine is controlled from the main duplex control board located on the turbine room floor. Instruments, recorders, annunciator, and control switches are on the front panels; sequence and protective relays on the rear.

In an installation of this type, many conditions must be checked before the turbine can be started safely. Starting and stopping the unit includes steps that must be performed in correct sequence and at proper time intervals. Automatic control is provided to relieve the operator of most of the routine and responsibility of performing and checking each step for starting and stopping.

In designing the control, principles well established in other applications were used to full advantage. Such principles include use of station battery, selective fusing of control and trip circuits, and interlocking of sequence and timing functions to obtain maximum reliability, and safety. Protective devices are grouped so that they are selective in the manner in which the unit is shut down.

All automatic control functions are directed by a master relay that must be energized by the master control circuit before the unit can be started. The master control circuit includes protective relays and other devices that check that normal conditions exist before starting can begin.

While the actual starting sequence is automatic, the operator must first energize the control circuits, check the position of certain selector switches, and start the cooling water, fuel oil, and auxiliary lubricating oil pumps before operating the master control switch to the start position. After the sequence has progressed through the various steps required in starting and accelerating the unit, the operator must synchronize the generator and pickup load.

The normal shutdown sequence is almost all automatic. After the generator has been disconnected from the bus, operation of the master control switch to the stop position will initiate the various steps required for shutdown. Provision has been made for automatically putting the unit on turning gear for a time after shutdown to permit cooling.

A selector switch is provided to interrupt the starting sequence at several selected points for testing or to facilitate calibration of protective and control devices.

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Local Wire Television Networks

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A new local video distribution system has been developed which provides equalization and amplification of signals transmitted over links between television studios, transmitters, coaxial cables, and microwave networks. The equipment consists of a transmitting terminal, an intermediate repeater with cable equalizers, and a receiving terminal.

A SATISFACTORY local video distribution system is necessary to interconnect television studios, transmitters, and pickup points within a city and to connect them to the coaxial cable and microwave intercity television networks. Wire extension circuits are also necessary to distribute video signals from local microwave circuits which are used to pick up remote program material. A local video distribution system has been developed for the Bell Telephone system utilizing existing telephone facilities as much as practicable.

It is the purpose of this article to describe these video transmission facilities and to show the results obtained with some typical circuit applications.

CHARACTERISTICS OF CABLE PLANT

THE CABLE PLANT in the local exchange areas available for video transmission consists of coaxial cables, existing interoffice trunk and subscriber paper-insulated cables, and shielded polyethylene string and tape insulated cables.

Shielded Video Cable Pairs. A new video cable pair has been developed to meet the demands of the backbone circuits. The high-frequency loss has been kept low by the use of large conductors and polyethylene insulation. The impulse noise and crosstalk have been reduced by shielding the balanced pairs. It is known as *16PSV* (polyethylene shielded video). As shown in Figure 1 each Number 16 American Wire Gauge copper conductor is insulated with a spirally wound polyethylene string and tape. Two spirally wound 3-mil copper tapes with opposite lay then are placed around a pair of the insulated conductors to form the shielded pair. The *16PSV* shielded pairs then are placed in their own lead sheath or in with other paper pairs in large interoffice trunk cables. The average near-end 4-megacycle crosstalk loss between the shielded pairs installed in this manner is about 120 decibels.

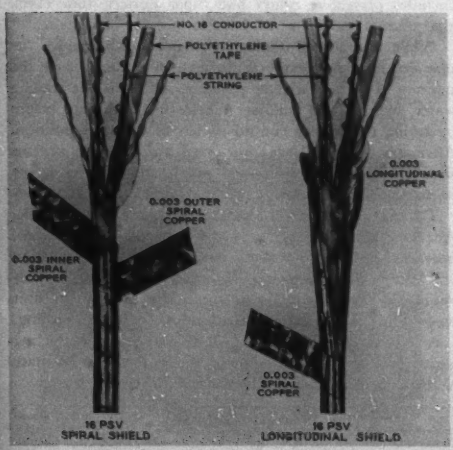

Figure 1. Newly developed shielded video cables for use in telephone plant

A modified design now is being produced. The inner shield is a 3-mil longitudinal-seam copper tape with one 3-mil outside spiral tape. The new design has one decibel lower attenuation and about 25 decibels lower crosstalk at 4 megacycles. The impulse noise also is expected to be considerably lower on the new design.

Representative attenuation and impedance characteristics of the shielded video pairs are given in Figure 2. The 4-megacycle loss of the *16PSV* spiral-shield and longitudinal-shield cable is seen to be 18 decibels and 17 decibels per mile respectively. The attenuation-temperature change for a seasonal underground temperature range of 26 degrees Fahrenheit is 0.45 decibel per mile, which is 13 per cent of that for 22-gauge paper pair.

Another cable known as *754C* has been provided for wiring within an office, for quick installations, or when only one or a small number of low-loss circuits are required, usually from an office to a broadcaster. This cable uses solid polyethylene insulation covered with a double braided copper shield which has an outside jacket of grey polyvinyl chloride. The near-end 4-megacycle crosstalk loss between two adjacent *754C* shielded cables is approximately 150 decibels. It is moisture resistant and may be pulled into underground cable ducts.

As previously indicated the near-end 4-megacycle crosstalk is respectively 120 and 145 decibels for the spiral- and longitudinal-shield cables. Experience to date indicates that for the average crosstalk of 120 decibels from the spiral-shield cable, ten tandem repeater links of about

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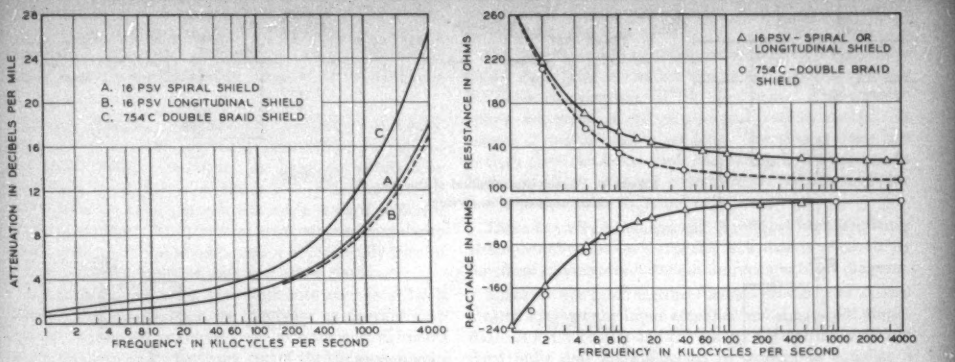

ATTENUATION IN DECIBELS PER MILE
A. 16 PSV SPIRAL SHIELD
B. 16 PSV LONGITUDINAL SHIELD
C. 754C DOUBLE BRAID SHIELD
FREQUENCY IN KILOCYCLES PER SECOND
RESISTANCE IN OHMS
△ 16PSV - SPIRAL OR LONGITUDINAL SHIELD
○ 754C - DOUBLE BRAID SHIELD
REACTANCE IN OHMS
FREQUENCY IN KILOCYCLES PER SECOND

Figure 2. Attenuation (left) and impedance (right) of newly developed shielded video cables for use in the telephone plant

85 decibels each at four megacycles should result in substantially no impairment in picture quality due to crosstalk and office impulse noise. This assumes that the gain and equalization in each repeater is sufficient to make up for the preceding length of cable. However, office spacings and especially repeater spacings of such great lengths and numbers are not expected to occur frequently. Therefore, it should be satisfactory to operate occasional repeater spacings of five to ten decibels longer if repeaters are provided with sufficient gain, equalization, and shielding for the purpose. An example of a 90-decibel repeater section is discussed in the special *A2* repeater application illustrated in Figure 12.

A2 VIDEO TRANSMISSION SYSTEM

THE *A2* system at the present time is made up of a transmitting and receiving terminal and the necessary number of intermediate repeaters for the length of the cable circuit in use. The line equalization and most of the circuit gain is furnished by the repeater except in special cases.

Transmitting Terminal. The transmitting terminal consists simply of a repeating coil and associated jacks for most operational cases. The impedance ratio of the repeating coil is 75:110 ohms and is used to connect the 75-ohm unbalanced impedance of the broadcaster's signal circuit to the 110-ohm balanced transmission line.

The frequency characteristics of the *197A* and *197B* repeating coils are shown in Figure 3. The *197B* is a later design with a low-frequency cutoff at ten cycles per second. The use of repeating coils which remove the d-c and other low-frequency signal components is permissible if these signal components are reconstructed at the receiving end. The low-frequency components are restored by the clamper in the receiving terminal and the direct current is restored at the receiving tube.

In special cases the repeating coil may be replaced by an output amplifier having an unbalanced input impedance of 75 ohms and a balanced output impedance of 110 ohms. The maximum voltage gain is 30 decibels, which is adjustable from 20 to 30 decibels in 2-decibel steps. The normal output operating level is two volts, peak to peak, which may be increased three decibels for a maximum of three output amplifiers in a circuit.

When a predistorter is used, its loss must be made up by 20 decibels of gain to give the desired increase in the high-frequency signal components. This gain is furnished by the first repeater when a repeating coil is used in the transmitting terminal. This limits the length of the first repeater link to a maximum of 30 decibels or 1.7 miles of *16PSV*.

A special case exists when the distance to the first repeater office is greater than 1.7 miles. In this case an output amplifier is used to provide the gain for the predistorter and the output network. A maximum loss of 63 decibels or 3.5 miles to the first office repeater is then permissible.

Receiving Terminal. The receiving terminal arrangements are shown in Figure 4. A repeating coil is used to connect the balanced cable pair to the 75-ohm unbalanced circuits. The restorer is used ahead of the clamper, as shown, when the signal has been predistorted at the trans-

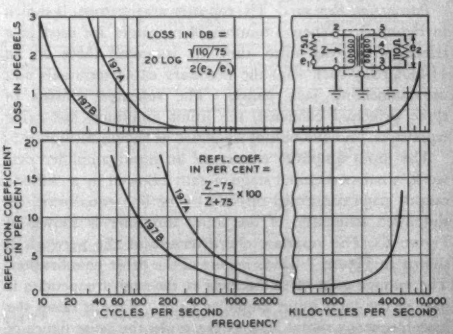


Figure 3. Transmission characteristics of video repeating coils (line transformers)

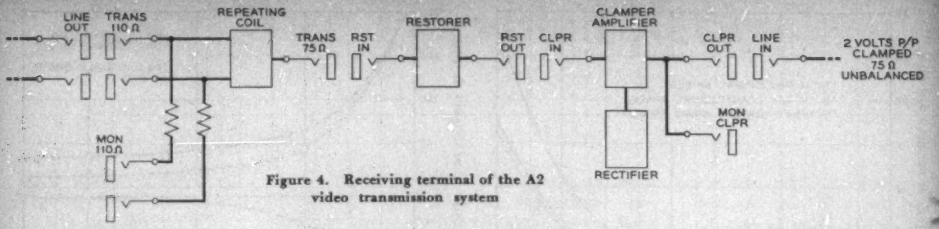


Figure 4. Receiving terminal of the A2 video transmission system

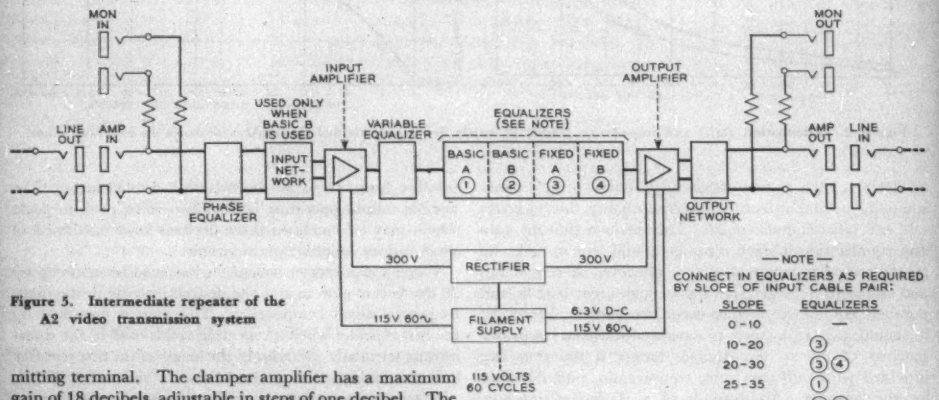


Figure 5. Intermediate repeater of the A2 video transmission system

mitting terminal. The clamper amplifier has a maximum gain of 18 decibels, adjustable in steps of one decibel. The signal delivered to the customer's 75-ohm load impedance is two volts, peak to peak, and clamped.

The *1B* clamper amplifier provides 18 decibels gain and a 31-decibel reduction of 60-cycle interference and a correction for a loss of low-frequency signal components. It is used in the receiving terminal for gain and to restore the low-frequency signal components after transmission through video repeating coils or over circuits whose length is such that increased low-frequency amplitude or phase distortions may result. The theory of design and the operation of this and other clampers has been presented elsewhere.[1]

Intermediate Repeater. The repeater arrangement is shown in Figure 5. When a number of repeaters are used in a telephone central office, they are mounted three on an 11-foot relay rack with the necessary cable terminals and interconnecting jack panels. The repeater consists of three principal elements, the input amplifier, the cable equalizers, and the output amplifier as shown in Figure 5.

The input amplifier consists of an input amplifier network, a balanced input stage of gain followed by a cathode output stage connected directly to the line equalizers. A simplified schematic of the input amplifier is shown in Figure 6. The response characteristic of the network is shown in Figure 7 which is part of the cable equalization. The voltage gain of 13 decibels at the high frequencies is part of the total input amplifier gain. Since it raises the high-frequency signal level at the grids, the noise figure of the input amplifier is improved 13 decibels. Provision is made to remove the input network when it is not needed as equalization or gain for short cable lengths.

The input longitudinal balance of the amplifier to keep down 60-cycle pickup is provided by the feedback resistance R_K and the balancing adjustment R_1.

The well-known methods of shunt peaking of the interstage plate resistance R_L are used to obtain a 6-megacycle band which has flat amplitude response and very small phase distortion out to four megacycles. The voltage gain of the input amplifier without the input network and terminated in the 1,000-ohm impedance of the cable equalizers is 14 decibels.

The output of the cable equalizer is terminated by the 1,000-ohm input impedance of the output amplifier. This amplifier has three unbalanced gain stages followed by a phase inverter and a balanced output stage. The balanced output stage feeds the balanced cable pair either through the amplifier network or from a 110-ohm termination when it is used as an intermediate repeater. The voltage gain without the output network, but terminated in 110 ohms, is 30 decibels. The normal output operating level is two volts, peak to peak, which may be increased three decibels for a maximum of three output amplifiers in a circuit. A simplified schematic is shown in Figure 8. The amplifier network is the same as the one used in the input amplifier having the response characteristic shown in Figure 7. Shunt peaking of the interstage plate resistances

is used to obtain a 6-megacycle band which has flat amplitude response and very small phase distortion out to four megacycles. Plate load decoupling is used in individual stages to obtain good transient response at the very low frequencies.

Over-all Repeater. The tandem operation of many repeaters requires that systematic irregularities be kept to very small limits. Therefore, the response below four megacycles is capable of adjustment to ±0.05 decibel in manufacture or subsequent maintenance work if sufficient care is exercised. The greatest part of this irregularity occurs above two megacycles, and it is practically zero in the more critical region of the band below 500 kc.

The common operating procedure is to receive a 2-volt peak to peak signal from the customer to operate each repeater output at two volts peak to peak and to return to the customer at the receiving end of the circuit two volts peak to peak into a 75-ohm load. The low-frequency loss of the cable pair may be anything from near zero for

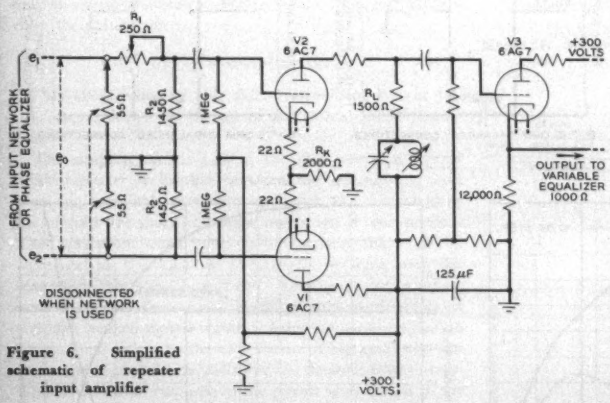


Figure 6. Simplified schematic of repeater input amplifier

very short circuits to five decibels for a 3.5-mile circuit of *16PSV*. Since the input amplifier operates directly from the line, its overload at low frequencies is important. The overload in the input amplifier and the output amplifier of a repeater has been kept low so that compression at operating signal levels is negligible with ten repeaters used in tandem.

Equalization of Cable Characteristic. The equalization of the cable characteristic is accomplished by using multiples of three constant resistance equalizer units located between the input and output amplifiers. These equalizers are referred to as basic, fixed, and variable.

The basic is always associated with an amplifier network. Referring to Figure 7, it will be seen that the sum of the characteristics of the amplifier network and the basic equalizer gives curve *C* which is the inverse characteristic of *16PSV* cable loss. It has been plotted as response instead of loss so it may be easily recognized as proportional to the *16PSV* cable characteristic shown on Figure 2. This combination of units will equalize 25 decibels of 4-megacycle *16PSV* cable loss.

The fixed unit will equalize ten decibels of 4-megacycle *16PSV* loss. The 10-decibel step of the variable unit has the same characteristic as the fixed unit. The variable unit is adjustable in 12 proportional 1-decibel steps. It consists of two sections in tandem. The sum of these two sections gives the desired loss characteristic *C* as shown in Figure 9. Each section is independently adjustable to give the 12 proportional 1-decibel steps.

There is a very small amount of residual high-frequency phase deviation in each repeater link that is removed by the phase equalizer indicated in the repeater block diagram.

Space for five cable equalizer units is provided on a panel located between the input amplifier and the output amplifier. A variable unit and the correct number of basic and fixed units thus are connected in tandem to equalize a given length of cable preceding a repeater. Since there can be a maximum of two amplifier networks per repeater, a maximum of two basic equalizers may be utilized per repeater. The first of these two networks to be utilized in equalizing a line is the output network at the preceding repeater. If the 4-megacycle line loss is 50 decibels or greater, the repeater input network then is added. Fixed and variable equalizers then are added as needed for longer lengths of cable. The gain of the amplifiers with the equalization that is provided allows for a maximum repeater spacing of about 3.5 miles of spirally shielded *16PSV* or 63 decibels' line loss at four megacycles. The general result of the equalizer loss is to attenuate low frequencies more than high

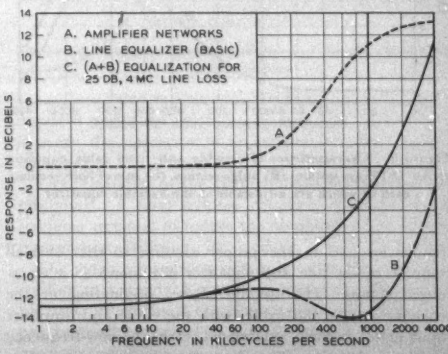
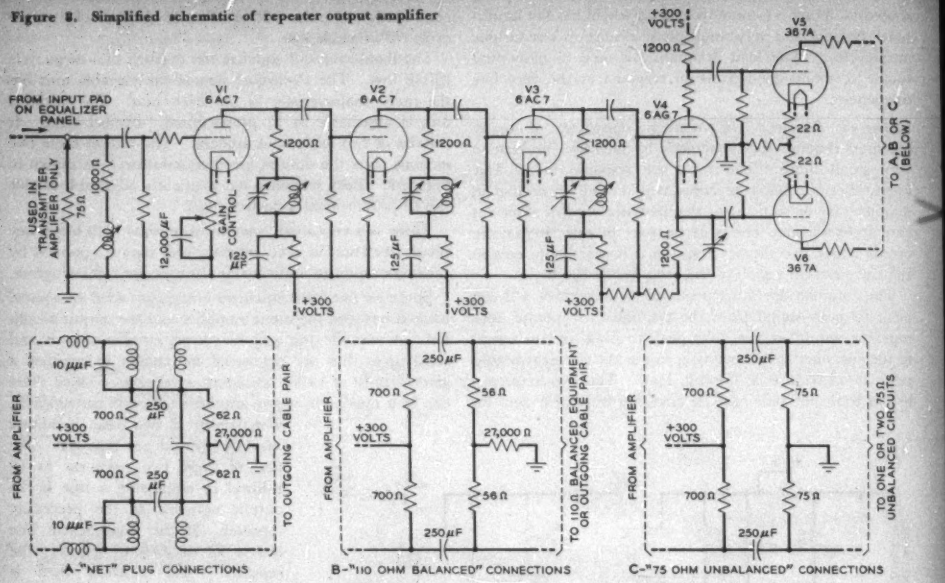


Figure 7. Characteristics of cable equalizers. (A) Amplifier networks, (B) basic 16PSV cable equalizer, (C) sum of amplifier network and basic equalizer for 4-megacycle cable loss of 25 decibels

Figure 8. Simplified schematic of repeater output amplifier



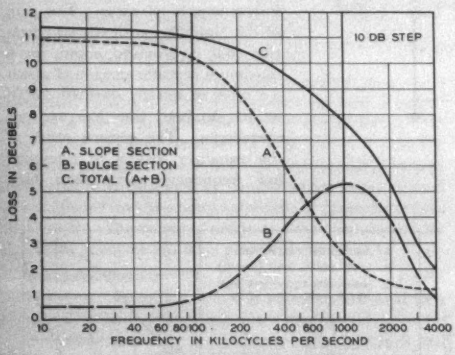


Figure 9. Characteristics of variable and fixed cable equalizer units. (A) Slope section, (B) bulge section, (C) sum of both sections, each of which are adjustable in the variable equalizer

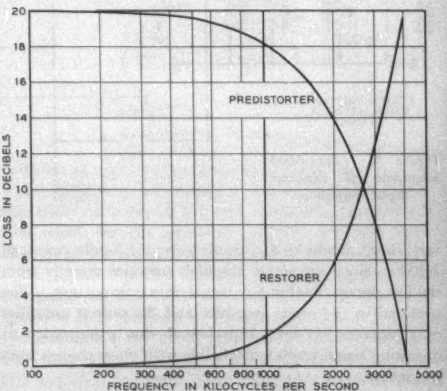


Figure 10. Loss characteristics of predistorter and restorer networks used for noise protection

frequencies and in the proper amount so that over-all response of the line and equalizer is uniform to a transmitted signal. The impulse noise, originating at the receiving end of the cable, with the cable and amplifier input noise, become attenuated with the low-frequency signal components. Therefore, there is a noise reduction in the low-frequency region. There is, also, a reduction in the interfering effect of the noise due to its concentration in the high-frequency band. The use of the output network at the preceding repeater as part of line equalization increases the high-frequency sending level 13 decibels without increasing the overloading in the output amplifier. This results in an added noise improvement of 13 decibels.

Noise Reduction by Signal Predistortion. The use of the predistorter at the transmitting terminal results in an added noise reduction for long repeater links. The pre-

distorter characteristic is given in Figure 10. The 20-decibel low-frequency loss is made up at the first repeater. When 20 decibels of gain are used at the first repeater to make up for the 20-decibel low-frequency loss of the predistorter, the high-frequency signal components thereby are increased on the outgoing line. This predistorted signal shape is retained throughout the remainder of the circuit.

It is eventually restored to its original shape at the receiving terminal by the use of a complementary equalizer characteristic, shown in Figure 10. Since this restorer has the high loss characteristic shown at the high frequencies it, also, attenuates high-frequency noise. This results in an average improvement in signal-to-impulse noise of 16 decibels and an improvement of almost 20 decibels in the signal-to-random noise from the cable and input amplifier. However, this reduction of noise is not obtained without some penalty. The load capacity of the repeater output stage must be increased some four decibels because of the adverse peak factor of the pre-equalized signal. The net gain in signal-to-noise ratio is, therefore, four decibels less than the values given.

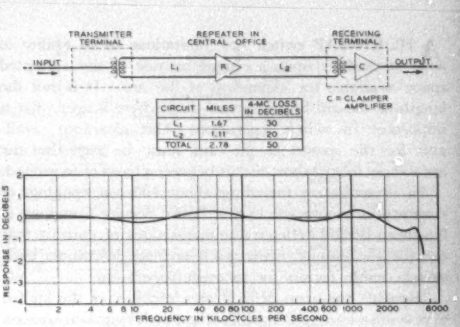
CIRCUIT APPLICATION

THE APPLICATION of this video transmission system can best be shown by the use of two typical *16PSV* circuit cases.

The simplest circuit case is the one where a central office repeater is located between the transmitting and receiving terminals as shown in Figure 11. In this case the circuits are short and noise protection is not needed. The maximum cable slope characteristic that can be equalized in this case is $L_1+L_2=69$ decibels, with the restriction that $L_2 \leq 27$ decibels. This restriction is necessary to prevent the output amplifier from overloading on the high peaked signals resulting from the pre-equalization for the final link. In the case shown in Figure 11 the loss of L_1 and L_2 are 32 decibels and 20 decibels respectively. The transmission response of the circuit is as shown in the figure.

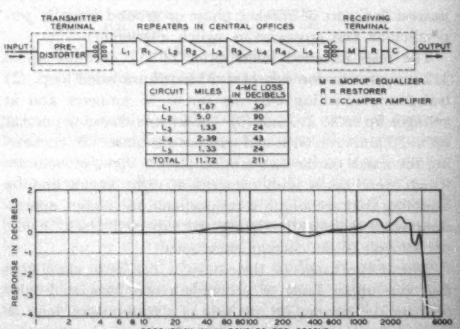
A more complex circuit application is illustrated in Figure 12. The total length of the five video lines is 11.72 miles having a total 4-megacycle loss of 211 decibels. Also, it will be observed that line L_3 is five miles in length with a 4-megacycle loss of 90 decibels and the normal operating procedures must be modified to accommodate this special case.

There is not enough gain or equalization in repeater R_3 to operate a 90-decibel line. However, it is accomplished in this case by altering the operating procedure in three ways. First, it is permissible to operate the output of repeater R_1 at a level which is 3.5 decibels higher than normal. Second, since line L_3 is short the output network in repeater R_2 can be used in the equalization of line L_3. This equalization occurs in the form of 13 decibels of high-frequency gain instead of low-frequency loss. Third, since line L_3 is short there is no noise protection problem at repeater R_3, so the output level of repeater R_3 can be operated the necessary ten decibels lower than normal. The signal arrives at repeater R_3 ten decibels lower than normal and is raised to normal by use of excess gain in repeater R_3. In this manner the 27 decibels of gain has been obtained to increase the normal repeater spacing of 63 decibels to 90 decibels. This cannot always be done, however, and it is seldom desirable to deviate from a



CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	1.11	20
TOTAL	2.78	50

Figure 11. Simple circuit application of the A2 video transmission system



CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	5.0	90
L_3	1.33	24
L_4	2.39	43
L_5	1.33	24
TOTAL	11.72	211

Figure 12. Complex circuit application of the A2 video transmission system

standard operating procedure, but in this particular case it made the operation of an off-premise extra repeater unnecessary.

The remainder of the circuit follows normal operating procedure. A final mop-up equalizer is located at the receiving terminal to reduce the amplitude of the residual transmission distortion characteristic.

The video transmission system is ordinarily applied according to a standard operating procedure. However, it has been shown by a complex circuit application that it can be flexibly applied to care for difficult nonstandard operating conditions.

REFERENCE

1. **Clampers in Video Transmission, S. Doba, Jr., J. W. Rieke.** AIEE *Transactions*, volume 69, part I, 1950, pages 477–87.

Interrupting Ability of Horn-Gap Switches

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A HORN-GAP switch has limitations in its ability to successfully open a circuit because of the restricted space available for expansion of the arc. It is not the length of the arc but its spread, and where it goes, that is important in switch operation. The clearance available for the spread of the arc must be such that the arc cannot form a short circuit between phases or to ground.

An investigation including about 400 test openings of current has been made by the Public Service Company of Northern Illinois to determine magnitudes of current that can be successfully interrupted and to determine basic switch design factors for successful operation.

"Reach" has been defined as a measure of the spread to provide a criterion for comparison with switch clearances. Arc reach is defined as the distance from a point midway between the arc extremities to the most remote point of the arc at the time of its maximum length. Reach is most critical when its direction happens to be towards the nearest live part of another phase or ground (usually perpendicular and crosswise to switch alignment).

The tests included interruption of (1) currents up to 312 amperes in one side of a 33-kv transmission loop, (2) transformer exciting currents up to 35 amperes and at voltages up to 49 kv, and (3) 132-kv line charging current up to 20 amperes, with and without gas blast. By measuring the reach on the two motion picture views of each arc which were taken with cameras at right angles and by assuming that arc length is proportional to voltage, expressions were developed relating the expected reach in feet per kilovolt to the current interrupted.

Within the range of these tests it has been concluded that the upper limit of probable reach associated with opening the current on one side of a transmission loop or the exciting current of a transformer is

Range in Amperes	Probable Reach
0 to 100	$0.0165 \times \text{kv} \times I$
100 to 320	$1.65 \times \text{kv}$

where reach is in feet, kv is in rms kilovolts across the separated horns after opening, and I is the rms current interrupted in amperes. These limits are not applicable to interruption of line charging current or static capacitors on account of the "trapped charge" after opening.

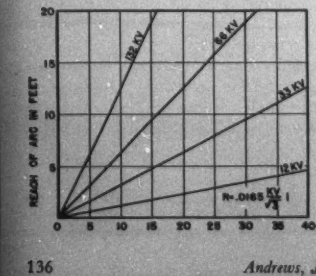

Figure 1. Arc reach for small currents at various line voltages

Figure 1 shows the reach of arc in feet plotted against resistive or inductive current interrupted. It is particularly applicable for determining reach when opening transformer exciting current. Similar graphs can be plotted for opening loop current, each curve representing either voltage across the open switch gap or loop impedance. In the latter case the range of voltages across the switch gap is much lower (usually from 5 to 40 per cent of nominal line to neutral voltage). In applying the formulae given previously for probable reach, the voltage must be determined for a given current. In the case of dropping load such as opening transformer exciting current, the voltage is that between line and neutral of the supply. In opening loop current, it can usually be obtained with sufficient accuracy by multiplying the current to be interrupted by the impedance of the transmission loop which contains the line to be opened by the horn-gap switch. When the probable reach has been determined, it must be compared with the clearance of the switch. For successful operation some margin between reach and clearance should be allowed.

The 132-kv line tests covered interruption of charging current up to 20 amperes without gas blast and with nitrogen or air directed into the arc at 115 pounds per square inch. With switches having 16 feet of horizontal phase spacing, it was concluded that 132-kv charging current can be safely interrupted without gas blast up to seven amperes. The successful opening of currents as high as 20 amperes with arc lengths up to 123 feet and reaches up to 25 feet was due to the favorable wind direction.

MAJOR CONCLUSIONS

1. A horn-gap switch will successfully interrupt a current if its dimensions are adequate to permit the arc to grow to the critical length at which it goes out, unless the wind is blowing in line with the arcing horns.

2. For resistive and inductive loads reach for currents below 100 amperes depends on both voltage and current. Maximum reach for practical use in this range is 0.0165 foot per ampere per kilovolt across the open switch gap.

3. For resistive and inductive loads reach for currents from 100 to 320 amperes is proportional to voltage but independent of current magnitude. Maximum practical reach in this range is 1.65 feet per kilovolt across the switch gap.

4. On 132-kv switches having 16 feet of horizontal separation between phases, about seven amperes (approximately 17 miles of line) can be opened safely.

Digest of paper 50-161, "Interrupting Ability of Horn-Gap Switches," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Underground Conduit for Electric Power Systems

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ELECTRIC CONDUITS of one type or another have been in use since the beginning of the electric power industry. Construction practices and materials are fairly well standardized within companies. There is no accepted single standard for the industry, and it is probable that no single standard could be designed that would be satisfactory. However, since the fundamentals and basic design considerations are the same throughout the industry, any discussion concerning these principles is pertinent to all conduit design. In recent years, probably the only new development involving conduit construction is the installation of high-voltage transmission cable in steel pipe with gas or oil under high pressure. The cost and lack of flexibility usually restrict this new system to high-capacity transmission uses.

A standard underground conduit system can usually be adopted by a utility company which has, or is in the process of placing, its electric transmission and distribution facilities underground. In order to standardize, conduit material and design installation must be made to conform with general conditions. Special methods should be reserved for locations where, because of either cost or physical conditions, standard procedures would not be satisfactory.

Fundamentally, a conduit system is good or bad depending upon its suitability for the installation, operation, protection, and maintenance of the cables which it is to contain. Fundamentals and basic considerations for conduit design and the construction of conduit systems are not essentially different now than they have been in the past, but progress in the art of electric transmission frequently adds or detracts emphasis to certain features of conduit design. For example, the growing tendency to install cables of greater capacity and to carry greater loads in existing systems requires that serious consideration be given to the thermal characteristics of a conduit system.

The complexity of the design problems pertaining to an underground conduit system will depend on whether it is intended as a new system in which there will be a greater flexibility of choice with respect to materials and methods or whether it is intended to extend or modify an existing underground conduit system. Co-ordination and compromise are necessary to attain the most satisfactory electrical, mechanical, and economical arrangement.

A basic requirement for a conduit design is to know the maximum permissible length of the conduit section between manholes or splicing chambers. This is a controversial subject dependent upon permissible cable-pulling stresses and friction factors of the conduit; there are nearly as many rules for determining this length as there are electrical companies. Having determined the maximum length of straight conduit sections between manholes, the next controversial item is the effect of bends of varying degree and radii. In the design of a conduit system, bends of varying degree may be expressed as equivalent lengths of straight conduit. This equivalent length varies, depending upon the distance of the bend from the cable feeding end of the conduit section. Based on a series of tests, a chart has been prepared from which these equivalent lengths can be determined readily and rapidly. A significant fact, developed during the studies, is that within reasonable limits the radius of the bend does not affect its equivalent length. The fact that a bend of larger radius has a greater over-all length is the compensating feature.

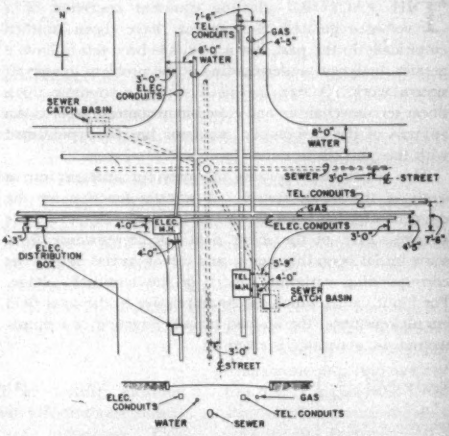

Figure 1. Typical utility lanes in the street

Street layouts are of prime importance in the design of a conduit system. It is important that a conduit system be installed in a location convenient for distribution purposes and still so located that the likelihood of interference from foreign constructions is remote. This frequently involves obtaining satisfactory agreement with local municipal authorities and other utilities in order to preserve an orderly and satisfactory arrangement of all structures in a street (see Figure 1).

Both the designer and the builder should constantly keep in mind that not only must a conduit system be structurally satisfactory but it must meet requirements for good cable installation, operation, and maintenance.

Digest of paper 50-237, "Underground Conduit for Electric Power Systems—Fundamentals and Basic Design Considerations," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Voltage-Regulated D-C Systems

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THE FACTORS affecting transient operation of a voltage-regulated d-c system have been studied empirically in the past, but a need has been felt to have a greater analytical understanding of the problem in aircraft system work. A step in this direction is to draw upon linear servomechanism and closed-loop control theory. An analysis of the carbon-pile regulator has been published with this purpose in mind.[1]

This article incorporates the previous analysis into a study of the whole system. A transfer function for the d-c generator has been derived taking as the input variable changes, $R(t)$, of the shunt field circuit resistance from some initial operating point, and taking as the output the corresponding variations, $E_0(t)$, of the terminal voltage. For input values which are small relative to the total field circuit resistance, the no-load transfer function of a shunt-wound d-c generator is given by

$$T_g(s) = +K_g\left(\frac{\alpha_g}{s+\alpha_g}\right) \tag{1}$$

where

$$K_g = \frac{K_s}{R_1 - K_s} \text{ and } \alpha_g = \frac{R_1 - K_s}{L_f}$$

and K_s is the slope of the no-load saturation curve at the operating point; R_1 is the shunt field circuit resistance at the initial operating point; and L_f is the incremental self-inductance of the shunt field circuit.

The carbon-pile regulator transfer function is the resistance output divided by voltage input and can be approximated by

$$T_r = K_r\left(\frac{\alpha_r}{s+\alpha_r}\right) \tag{2}$$

where

$$K_r = \frac{UP}{KR_c}$$

$$\alpha_r = \frac{R_cK}{U^2+KL}$$

where U is a magnetic coupling coefficient; P is the rate of change of carbon-pile resistance per change of carbon-pile stack length; R_c and L are the resistance and incremental self-inductance of the operating coil circuit; and K is the difference in slopes of magnets and carbon-pile force deflection curves.

The system comprised of a single shunt generator with carbon-pile voltage regulator can be represented schematically by a block diagram shown in Figure 1. Disturbances such as load changes can be translated into equivalent voltage inputs E_t and E_t', and the transform of the resulting terminal voltage transient is given by

$$\epsilon_1(s) = E_t'(s)\left(\frac{T_g}{1-\frac{E_0}{\epsilon_1}(s)}\right) + E_t(s)\left(\frac{1}{1-\frac{E_0}{\epsilon_1}(s)}\right) \tag{3}$$

Figure 2 shows a measured terminal voltage transient resulting from the removal of full load from the system and shows also the response as calculated from equation 3.

It can be shown that in the case of load current changes the only equivalent voltage inputs which affect the generator terminal voltage are those due to the change of the voltage drop in the armature resistance drop and the self-inductance of the armature circuit (including commutating and compensating windings) during the load removal. It also can be shown that excellent qualitative predictions of system stability and performance can be obtained by examining the loop transfer function, $(E_0/\epsilon_1)(s)$, in the vicinity of the $1+j0$ point.

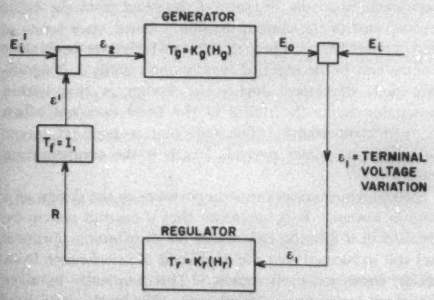

Figure 1. Block diagram of system consisting of shunt generator and carbon-pile voltage regulator

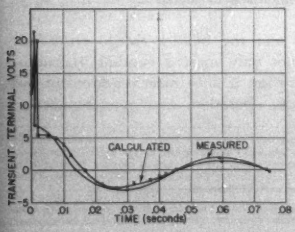

Figure 2. Measured and calculated system response to removal of full load

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Ice Testing of Outdoor Disconnecting Switches to Simulate Field Conditions

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THE ICE STORM is one of the major difficulties encountered in the operation of electric power systems. Under certain atmospheric conditions a deposit of hard clear ice can build up in a few hours to a thickness which causes overhead lines to fail, and which renders the operation of outdoor switching equipment very difficult. To overcome operating difficulties under these conditions many ingenious outdoor switches which employ some auxiliary blade motion to break ice have been developed. This blade motion has been accomplished by a great variety of mechanisms, and doubtless many other different varieties will follow.

The testing of these outdoor switches to determine the effectiveness of their ice-breaking mechanisms has long been a problem to both switch manufacturers and power system engineers. In most locations, severe ice storms occur infrequently so that testing under natural conditions becomes impractical. Thus the problem arises of producing artificially the thickness and density of ice coating which occurs in nature. If any outdoor switch were frozen in a giant ice cube large enough to contain the entire switch, obviously it would be inoperable. Therefore, testing must be done with an ice thickness comparable to that actually encountered in service. Also, the strength and tenacity of an ice coating varies considerably with variations in the air temperature, water temperature, and rate of application. These factors must be controlled carefully to obtain proper results. It is the purpose of this article to describe an ice test which produces conditions comparable to those obtained in the field, and to describe the design features of a switch which can be operated easily under severe icing conditions.

The problems involved in testing outdoor switches to determine their effectiveness as ice-breaking mechanisms are numerous. This article describes an ice test and the design features of a switch which can be operated under severe icing conditions.

FORMATION OF ICE

THE WEATHER conditions which most often produce severe ice storms are those which prevail when a warm air mass has overrun a cold air mass so that rain is falling through air which is slightly below freezing. Such warm fronts usually extend over a considerable area producing wide precipitation belts, and these fronts are slow moving compared to cold fronts so that the rain may persist for a number of hours.

Under the conditions described, the falling water is cooled by evaporation and by its travel through the cool air mass so that it freezes almost instantly upon contact with objects on the earth. When the temperature of the air near the ground is only a few degrees below freezing, the ice which is formed is hard and clear and free from the inclusion of air bubbles. This is the kind of coating which creates the greatest difficulty in switch operation.

In general, ice which is formed at a very low temperature (below 15 degrees Fahrenheit) and ice which is formed from moisture condensing from the air onto cold surfaces has a very porous and weak structure.[2] Such ice is called rime ice and is characterized by a white, rather than a clear, appearance. This appearance is a result of the many small air spaces included in the structure. A good example of rime ice is the formation on the cooling coils of a home refrigerator.

It has been found that if switches are cooled to temperatures below 15 degrees Fahrenheit and are sprayed with a fine mist, a coating of rime ice is deposited. This coating is very easily broken even when the thickness is great, and such a test is not a real measure of the ice-breaking ability of the mechanism.

A test which has been found to give consistently a clear hard ice deposit is as follows:

1. Assemble all poles and mechanism of the switch on a structure to permit normal operation. The operating pipes may be shortened in order to suit any space requirements.

2. Clean all traces of oil or grease from all outside switch surfaces. Even thin films of oil or grease prevent ice from adhering to the switch and greatly change test results.

3. With the switch blade in the desired position, lower the air temperature to 35 degrees Fahrenheit and then spray the switch with water which has been cooled to approximately 35 degrees Fahrenheit. This spray should be arranged to simulate a general rain and not a fog or mist. The water should fall from above and at an angle not exceeding 45 degrees from vertical. The location of the water spray should be such that the pole units and

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the entire operating mechanism are covered with a uniform rainfall.

4. After the rain is started, the air temperature should be lowered at the rate of approximately 3 degrees Fahrenheit per hour to a final temperature of 25 degrees Fahrenheit. This causes the switch to be sprayed for an hour before freezing temperature is reached, and the switch is thoroughly wet when freezing begins. The amount of water supplied should be such that ice forms at the rate of about 1/4-inch per hour.

5. Continue the spraying while holding the air temperature between 25 and 30 degrees Fahrenheit until a deposit of ice one inch thick has formed.

6. After the ice has been deposited, the switch may be operated and the operating effort noted.

TYPICAL TEST ARRANGEMENT

A LABORATORY setup to make the test described above is shown in Figure 1. The switches which were tested were two 15-kv 400-ampere 3-pole manually gang-operated air switches with offset torsional mechanisms. Figure 1 also shows the pipes which comprised the spraying system to create the rain on the switches. These pipes were located at the level of the switch bases and were

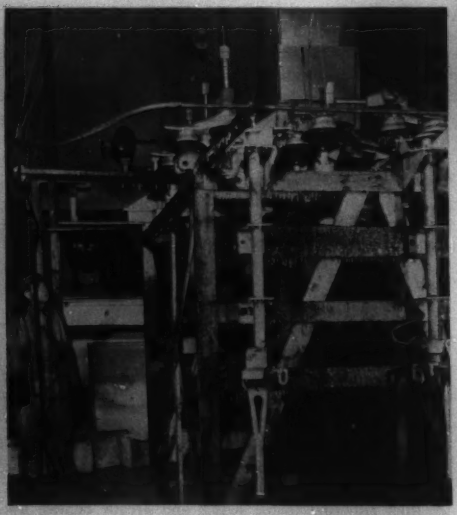

Figure 1. Setup for the ice test of two 15-kv 400-ampere air switches

supplied with water cooled to 35 degrees Fahrenheit by being circulated through a coil embedded in dry ice. The pipes were 1/2-inch thin-wall brass tubing and were drilled with 0.028-inch diameter holes on 9-inch centers to release the spray.

The water pressure was adjusted so that the streams would rise about six feet into the air before falling onto the switches. With this particular arrangement 1.5 gallons of precooled water were sprayed per hour per square foot of area sprayed to cause the ice to form at the desired rate. An air blower in the cold chamber served to agitate the rainfall to assist in uniform distribution over the switch.

Figure 2 shows the arrangement used to precool the water for the rain. Tap water was used, and it was cooled by being passed through 120 feet of 1/2-inch copper tubing wound into a coil surrounded with dry ice. The coil was placed in a micarta tube approximately 16 inches in diameter and 30 inches long. Dry ice chips were packed in the center of the coil. The output water temperature was controlled by varying the amount of dry ice which was used and the density of the packing of the chips in the center of the coil.

Figure 3 shows the clarity of the coating on the test

Figure 2. Dry-ice chamber for precooling water with which to spray switches

switches after ice has been deposited. After the switches were operated, they were placed in an intermediate position between open and closed, as shown in Figure 4, in which it can be seen how the blade twisting motion and the flexing of the jaws have cleared the ice from the contacts.

MEASUREMENT OF ICE THICKNESS

ONE OF the chief problems in making tests of this kind is that of knowing when the right quantity of ice has been deposited. Many utility company specifications have been studied, and "one inch of radial ice" is most commonly specified for testing of this kind. A final thickness of one inch is suggested as a standard for testing since this amount is rarely exceeded in service in the continental United States. However, ice does not form with uniform thickness over all switch surfaces, and the further problem arises of determining the correct place to measure the ice.

On a power transmission or distribution system which has been blanketed with an ice storm, the ice of greatest interest, and that which has the most nearly uniform thickness, is that formed on horizontal overhead conductors. Around these circular conductors ice is formed

with approximately uniform thickness. A measure of the radial thickness of the coating on a horizontal conduct is a fair measure of the severity of the storm which has occurred.

On outdoor air switches ice forms much more rapidly on some surfaces than others. Therefore, a measurement of the ice at any one place on the switch will probably not give a fair measure of the severity of the coating. One method which has given good results is to mount a piece of copper cable so that it is horizontal and receives the same rainfall as the switch. A measurement of the ice thickness at the top side of this conductor can be taken as an index of the thickness of the ice coating which has formed on the switches.

Many of the outdoor air switches now on the market have a single blade of circular section. A measure of the ice on the top side of the blade of such a switch in the closed position compares closely with ice on a circular conductor, and can be used as a measure of the severity of the ice storm.

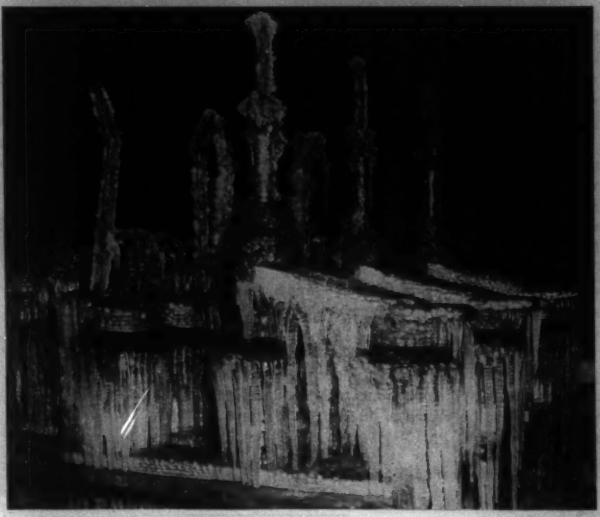

Figure 3. Close-up view of final ice coating showing the exceptionally heavy clear ice coating

Figure 4. Close-up view of switch pole units with each switch in an intermediate position after being operated

DESIGN FEATURES

In developing the ice tests described in this article, a great number of tests were made on a variety of switches, and certan desirable features of design for ice-breaking switches were determined (see Figure 5).

An ideal design for an air switch to operate when covered with ice is one in which all moving parts are totally enclosed and cannot accumulate ice. Obviously, a practical design cannot enclose the blade and break jaw, and there is a need for auxiliary blade motion to break ice on the jaw. Many such motions have been devised, one of the most popular being a blade twisting motion that takes place before blade rise begins. In general, this motion is very effective in clearing the jaw of ice, provided the mechanism used to obtain the blade motion does not itself become fouled with ice. It is possible to design a mechanism which is itself entirely enclosed and protected from icing; such a mechanism is described by H. W. Graybill and J. S. Ferguson.[1] This mechanism is employed in the switch described here. Thus, the first feature of switches which have been designed to work under ice conditions should be an enclosed-blade actuating mechanism.

The tests which have been described revealed further that the hinge-end contact was another source of difficulty under ice conditions. Switches were tested which had jaw

contacts at the hinge, similar to those used at the break end. These hinge jaws gathered ice and increased the initial effort required to start the switch moving. Switches which have totally enclosed hinge contacts showed a considerable reduction in operating effort under ice conditions of the test.

It also was made apparent during the testing of these switches that adjacent switch parts with relative motion should be widely spaced. Any flat surface which was required to move with respect to a closely adjacent parallel stationary surface was particularly troublesome. Ice bridging between these surfaces was very difficult to break. Therefore, a third feature of ice-breaking switches is to design the switches so that they have freedom from closely spaced parallel surfaces which have relative motion during switch operation.

Figure 6 shows a pole unit of a switch which was especially designed to operate under the most severe ice coatings, and which incorporates all of the features which were found to be desirable in the testing program described here.

SUMMARY

AT PRESENT, there is no standardized method of testing outdoor air switches to evaluate their performance when covered with ice. A careful study has been made of the problem of producing ice in artificially cooled rooms which corresponds in density and strength of bonding with that encountered in service. The essential elements of a testing procedure to give the desired results are as follows:

1. A complete switch is assembled for normal operation, and all traces of oil or grease are cleaned from switch surfaces.
2. The air temperature is lowered to 35 degrees Fahrenheit and a general rain of water which has been precooled to 35 degrees Fahrenheit is started.
3. After the rain has been started, the air temperature is lowered approximately 3 degrees Fahrenheit per hour until a final temperature of 25 degrees Fahrenheit has been reached.
4. The rain is continued with the air temperature at 25 degrees until an ice thickness of one inch has been reached on the top of the switch blade or on a horizontal conductor receiving the same rain as the switch.
5. The switch is operated and the operating effort noted.

During the testing of many switches using these specifications, certain important features of design for ice-breaking switches were determined. These features are as follows:

1. An auxiliary ice-breaking motion should be imparted to the blade before blade rise begins. The mechanism which imparts this motion to the blade should be enclosed and protected from ice accumulations in both open and closed positions.
2. The hinge-end electrical contacts should be protected from ice accumulation.
3. Closely spaced parallel parts which have relative motion during switch operation should be avoided in all cases.

It is suggested that the testing method developed be considered as a standard procedure for outdoor switch testing.

Figure 6. Pole unit of a switch especially designed to have good performance under heavy ice coatings

Figure 5. Setup for testing the performance of 115-kv 1,200-ampere switches

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Finite Representation of Impulse Functions

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TRANSIENT PROBLEMS, such as closing a switch at a certain time, or throwing a load on a machine suddenly, or applying an impulse to a system, involve the use of discontinuous functions. These may be expressed in one type of notation by multiplying any given function by the Heaviside Null Unit Function $H(x,x_0)$, which is equal to zero when $x<x_0$ and is equal to unity when $x>x_0$. Similarly, in studying the fields due to point sources in a continuous medium the impulse function which is the derivative of the Null Unit Function $H'(x,x_0)$ arises.

Until the recent development of Schwartz[1,2] no accepted mathematical method was available for handling such quantities as $H'(x,x_0)$ and its higher derivatives in a direct manner, although, as Schwartz points out, engineers and physicists had been dealing with such problems by methods of their own such as the operational calculus. In a 1949 paper[3] it was indicated how Schwartz's method could be applied successfully to such quantities when they arose in the solution of problems. In the same paper the solution to the same problems was given using $H'(x,x_0)$, $H''(x,x_0)\ldots$ in a formal manner.

Although the practical application of the Schwartz method has already been shown,[3] the theory on which it is based is somewhat advanced and this seems a deterrent to its exploitation to the fullest extent by engineers. A simpler method is to use differentials $d^nH(x,x_0)$ instead of differential coefficients $d^nH(x,x_0)/dx^n$ following the pattern used previously in the Stieltjes integral.

This procedure may be visualized by referring to Figure 1. In (*a*) the unit function $H(x,x_0)$ is shown, with a finite discontinuity equal to unity, at $x=x_0$. This graph is drawn in "unit" space, with ordinates plotted in finite units. In (*b*) is shown a common conception of the derivative $dH(x,x_0)/dx$, also in unit or function space. This is zero except at x_0, where it becomes infinite in such a way that the area of the "spike" representing it is equal to unity. In (*c*) a representation of $dH(x,x_0)$ is shown which is zero everywhere except at $x=x_0$ where it is equal to 1, or equivalent to a unit mass. It will be noted that this might be regarded as representing a compression of (*b*) in "Δx space" obtained by simply multiplying all the ordinates of (*b*) by dx. This scale reduction converts the infinite (linear) ordinate of (*b*) at $x=x_0$ to a unity (mass) ordinate in (*c*).

Hence, by this simple expedient of transforming into Δx space, with all ordinates reduced from reality by the multiplier dx, the representation of $H'(x,x_0)$ has a finite, instead of an infinite, value at $x=x_0$.

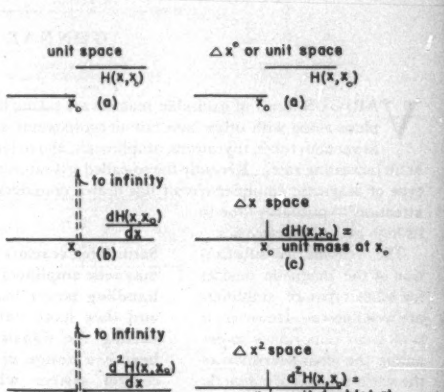

Figure 1. Null Unit Function and its first two derivatives in unit space and in Δx space

Evidently the same procedure, carried one step farther, into Δx^2 space, will make $d^2H(x,x_0)=dH(x,x_0)-dH(x-\Delta x,x_0)$. This may be regarded as a unit doublet, as shown in Figure 1(*e*). The usual representation of the second derivative $d^2H(x,x_0)/dx^2$ by two infinite plus and minus spikes, Figure 1(*d*), is compressed into the unit doublet by multiplying the unit space ordinates by dx^2.

For the case of the nth order it is readily shown

$$d^nH(x,x_0)=\sum_{r=1}^{r=n}(-1)^{r-1}\frac{(n-1)!}{r!}dH(x-(r-1)\Delta x,x_0)$$

and this can be interpreted as a unit n-tuplet at the point x_0 similar to the doublet above in the case of $d^2H(x,x_0)$. The nth derivative of $H(x,x_0)$ is obtained by dividing each side of the equation by dx^n.

In this way, equations including impulse functions can be rendered finite, permitting their solution by conventional methods but requiring that the equations hold in each of the Δx^n spaces involved.

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A Simple Magnetic Modulator for Conversion of Millivolt D-C Signals

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VARIOUS forms of saturable reactors are taking their place along with other basic circuit components, such as vacuum tubes, thyratrons, amplidynes, and so forth, at an increasing rate. Recently the so-called self-saturating type of magnetic amplifier circuit has drawn considerable attention[2-8] primarily due to its high gain characteristics.

The reasons for substitution of the magnetic devices for other types of amplifiers are well known. However, it is of great importance to examine the characteristics of the various forms of magnetic amplifiers purely from a performance standpoint, aside from service life, reliability, and other features, and to have a clear picture of those functions in which the magnetic devices can give superior performance.

Saturable reactors now are being used in magnetic amplifiers because they are capable of handling larger loads than vacuum tubes can and they have stable performance when converting d-c signals to alternating. Presented here is a design of a magnetic modulator in a control system which is otherwise entirely electronic.

It is found that saturable reactors have two interesting capabilities:

1. Capability of handling larger current and power than conveniently can be handled by the use of electron tubes.
2. Capability of converting low-voltage d-c signals into alternating current with a high degree of stability.

This article will discuss some aspects of the latter category of application.

Emphasis on these fields is increased by the demands which the high-gain-type magnetic amplifier circuits put on the associated rectifiers. These are often difficult to meet when a high degree of stability and linearity is required under adverse environmental conditions, such as are encountered in aircraft applications, for instance. In such cases it is often practical to use tube rectifiers.

As there is no appreciable difference between the reliability of a diode and that of a triode, it is sometimes thought that, as long as tubes have to be used in the circuit, one may as well utilize their gain, that is, in effect, use the vacuum tubes as grid-controlled rectifiers. The power gain in the magnetic amplifiers then becomes less important, while the possibilities they offer for the solution of such problems as are imposed, for instance, by signal sources like thermocouples, is of great value.

When gain is sacrificed, the performance of the magnetic amplifiers in other respects, such as linearity and speed of response, can be greatly improved. At the same time, simplifications of the magnetic amplifier circuit itself can often be made. The demands on the magnetic material also become different. Particularly high saturation flux density, for instance, is not necessary. On the other hand, the use of gapless cores becomes even more imperative. The lowered requirements for saturation flux density open possibilities to use core materials of the new, practically nonconductive ferromagnetic-spinel type. The ferromagnetic-spinel cores also have been found to be advantageous from a mechanical viewpoint, because they are not sensitive to handling as ordinary nickel-iron alloys are.

The viewpoints given here grew out of the design of a magnetic modulator to meet a specific need in an otherwise electronic control system.

The problem was to derive an a-c signal of the supply frequency, sinusoidal shape, constant phase, and with an amplitude proportional to the input, from a d-c signal with a maximum value of the order of 100 millivolts at an impedance of 1,000 ohms. The phase of the output voltage was to reverse as the polarity of the input signal reverses.

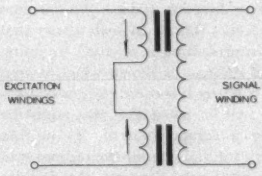

Figure 1. Schematic diagram of the basic modulating unit

Main emphasis was to be laid upon linearity, noncritical operation as to variations in supply voltages, adaptability to existing parts of the control system, general simplicity, and smallest possible size and weight.

In order to meet the requirement of a sinusoidal output of constant phase, it is necessary to operate over a small portion of the magnetization curve, in contrast to the high-excitation thyratron-like operation that is normally used in high-gain magnetic amplifiers.[8,9]

Traditionally, a magnetic amplifier of the push-pull or

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balance-detector type that is indicated here consists of four cores, equipped with three or four windings each, or the equivalent thereof in the form of a pair of 3-legged reactors. By some re-examination of the various needs of excitation, bias, and so forth, in the light of the general circuitry desired, available power sources, and possible short cuts in the particular case, it was found that a considerable simplification could be made.

The basic saturating unit finally chosen is shown schematically in Figure 1. An actually constructed unit is illustrated in Figure 2, under various stages of completion. The arrangement consists of only two saturable cores and a total of three windings. The principle of operation is described briefly: the two cores are excited by the same current and in opposite directions, so that no net voltage is induced in the signal winding. This symmetrical condition will be maintained even if a d-c component is added to the a-c excitation current, as the two cores still, at every moment, will be subject to a magnetizing force of equal strength but opposite sign.

If now a direct current is introduced in the control winding, the symmetry is disturbed and a voltage is induced in this winding. If the excitation current is pure alternating current, the induced voltage will consist of even harmonics of the excitation frequency. If a direct bias current is added, the induced voltage will consist mainly of the fundamental frequency.

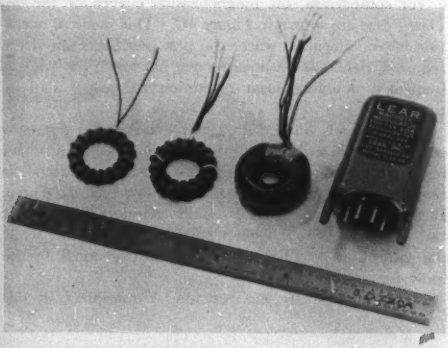

Figure 2. Magnetic modulator in various stages of completion. Left to right: a single core with excitation winding; a matched core pair, ready for signal winding; a completely wound unit; and a finished unit, magnetically shielded and hermetically sealed

A few possible application circuits for the device illustrated in Figures 1 and 2 are shown in Figure 3. Either series or parallel connections of the reactor, relative to the signal path, are possible. The circuit finally chosen for the solution of the specific problem mentioned previously is the series-connected type, with biased operation, Figure 3*D*. The practical advantages of the 2-core magnetic modulator can be summarized as follows:

1. In order to simplify the procedure of matching cores, it is highly desirable to reduce the number of saturable cores to a minimum.

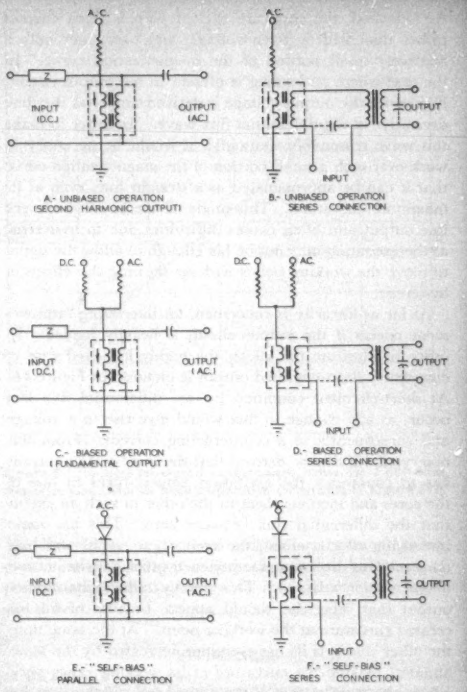

Figure 3. Magnetic modulator circuits using the basic modulating unit

2. In order to avoid any dependence of the balance upon any winding resistance values, it is desirable to transmit the energy from the excitation source purely through flux linkages, and to connect all excitation windings in series.

3. In order to obtain the largest possible number of control ampere turns, it is desirable to use the largest possible portion of the winding space for the control winding.

4. When a sinusoidal output current is desired, it has been found preferable to excite the modulator with a constant alternating current, rather than exciting it by a given voltage.

The various modes of operation are illustrated by the magnetization curves of Figure 4. The curves shown represent an idealized case, taking only the commutation curves into consideration. Major, as well as minor, hysteresis loops are disregarded for the sake of simplicity of reasoning.

The operation in the biased case, which perhaps is of the greatest practical interest, is shown in Figures 4*A* and 4*B*.

As indicated, the cores are excited with a given current rather than with a given voltage, and work over only a relatively small portion of the magnetization curve. In the case where no loading is present in the output circuit, Figure 4*A*, the output voltage is derived simply as the time derivative of the differential flux wave. In order to make this wave reasonably sinusoidal, it would be necessary to work over such a small portion of the magnetization curve that it can be approximated as a straight line, even at its maximum curvature. This mode of operation gives very low output and often causes difficulties due to hysteresis, as the excitation may not be big enough to allow the signal to move the working points without showing the effects of hysteresis.

As far as linearity is concerned, an interesting improvement occurs if the output circuit is heavily loaded. In order to illustrate the effect, the highly idealized case of completely short-circuited output is pictured in Figure 4*B*. At short-circuited condition no net differential flux can occur, as any change in flux would give rise to a voltage and consequently to a counteracting current. From this observation it can be derived that the short-circuit current has to counteract the excitation ampere-turns in one of the cores and increase them in the other to such an extent that the differential flux becomes zero. This has some interesting effects. First, the core where signal and bias ampere-turns are counteracting each other gets its net a-c magnetization reduced. This greatly reduces harmonics output that otherwise should appear because of the increased curvature at the working point. At the same time the other core gets its net excitation increased by the same amount, making the curvature of its working range very nearly the same as that of the other core. If this is to be accomplished exactly, the magnetization curve has to be part of a logarithmic curve. The ratio between excitation and output currents then becomes at every moment constant. Consequently they have to be of the same wave shape.

The interesting conclusion is then reached that under these circumstances sinusoidal excitation current gives rise to a sinusoidal short-circuit current, which is exactly in or out of phase with the excitation current; this occurs in spite of the nonlinear properties of the magnetic material. In accordance therewith, it has been found experimentally that the excitation current can be increased substantially before visible distortion occurs when the output circuit is heavily loaded. In fact, when ferromagnetic-spinel core materials are used, this mode of operation has been found to be the only practical one when a sine wave output is desired, because of the relatively large hysteresis effect these materials exhibit when they are subjected to excitation.

It should be noted that the action of a short-circuited magnetic modulator, in certain respects, is very similar to that of a current transformer. The output current is, for instance, proportional to the excitation current, but the output ampere-turns are not necessarily equal to the signal ampere-turns, as is the case in a normal, highly saturated reactor without feedback.[9] However, in practice it has been possible to obtain a linear relationship between the signal and output currents that is at least as good as the reading accuracy which is available on most ordinary laboratory meters.

For comparison, the magnetization curves for the unbiased case are shown in Figure 4*C*. This mode of operation is recommended where the best possible sensitivity is required, demands on linearity are not too high, and the frequency doubling from excitation to output can be tolerated.

The demands on the uniformity of the two magnetic cores in the described case differ from those of ordinary highly saturated operation in the respect that balance is required over the entire knee of the magnetization curve. In the highly saturated case usually considerable tolerance can be allowed on the steep portion of the curve, while the saturation flux has to be very nearly equal in the individual cores.

In order to satisfy the matching requirement in this

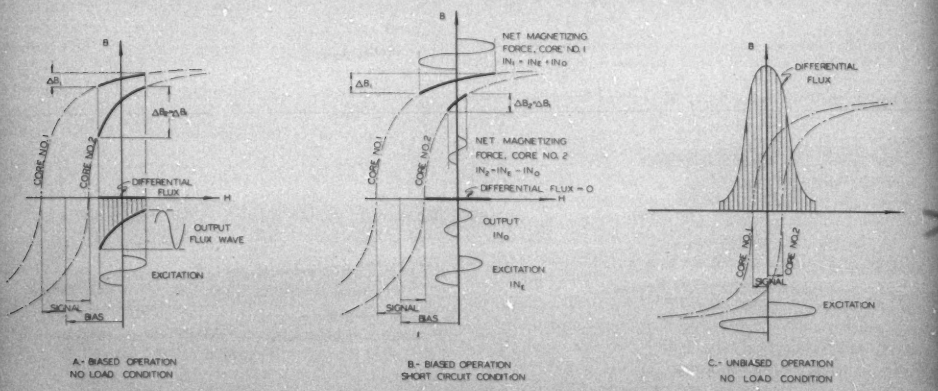

Figure 4. Magnetization curves showing the various modes of operation of the modulating unit

case it has been found imperative to use gapless cores. The toroidal shape was selected because of its maximum compactness for a desired performance. A laboratory setup for matching cores is shown in Figure 5. About 50 cores, with excitation windings put on, are threaded on a copper bar, forming a common 1-turn secondary. The differential voltage is measured when the cores are excited with the same bias and somewhat larger alternating current than they are intended to be used for, and the best pairs are selected.

A typical measured performance curve for a finished unit meeting the specification given in the beginning is shown in Figure 6. The core material in this particular case was a ferromagnetic spinel. As the wave form of the output voltage does not change appreciably with the signal strength, the linearity is equally good for the average or rms values or the fundamental sine wave of the output voltage.

The output current was found to be proportional to the excitation, while the variation in output for normal variations in bias current was smaller than a proportional quantity.

The property of having an output proportional to the excitation is shared by the magnetic modulator with several

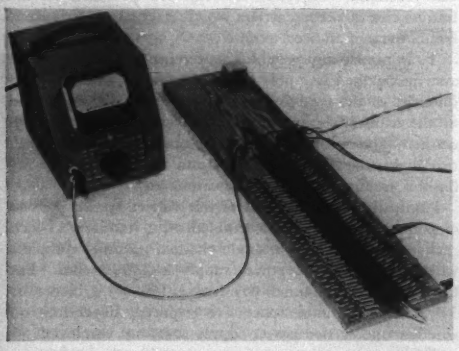

Figure 5. Laboratory setup for core matching

kinds of pickoffs commonly used in control systems, such as potentiometers, inductive pickoffs, and so forth. Therefore, this property is sometimes an advantage. If, for example, the output of a thermocouple has to be compared to that of a potentiometer, which is fed from the same line as the magnetic modulator, compensation for line-voltage variation is automatically achieved.

The performance illustrated in Figure 6 does not represent the ultimate possible sensitivity. In the written discussion to papers by A. G. Milnes[4] and H. M. Gale and P. D. Atkinson,[5] J. F. Coales has given a tabulation of various properties of the different kinds of amplifiers employing a modulated magnetic field. The input stability level is listed as from 10^{-8} all the way down to 10^{-17} watts.

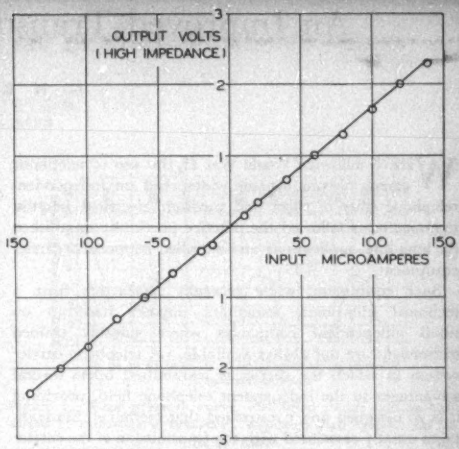

Figure 6. Typical measured performance curve for 1,000-ohm magnetic modulator in biased operation (schematic of Figure 3D)

The latter figure is obtained with an arrangement giving even harmonics output. These figures are indicative of possible applications of magnetic modulators in the small signal field.

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An Improved Transmitted Carrier System

G. H. BRODIE

WHEN, following World War II, the use of telephone carrier circuits became widespread on independent telephone lines of short and medium electrical lengths, manufacturers followed the practice previously established on long-line applications and supplied suppressed carrier equipment.

Such equipment, while generally satisfactory from a technical viewpoint, sometimes imposes hardship on small independent companies where suitably trained technicians are not always available. A telephone carrier system in which the carrier is transmitted offers several advantages to the independent telephone field, providing it is so designed and constructed that technical disadvantages usually associated with the transmission of the carrier are minimized or eliminated.

Compared with a typical suppressed carrier system, the chief advantages offered by a transmitted carrier system of suitable design and construction are as follows:

1. Neither synchronization of local and distant oscillators nor critical carrier leak adjustments are required.
2. The carrier-frequency signal can be traced through the entire system and measured easily when the channel is either in use or idle.
3. Ringdown signaling can be accomplished in a very simple and inexpensive manner.
4. Receiving oscillators are not required.
5. Voice-frequency shift is completely eliminated.
6. Neither additional pilot frequencies nor extra bands for signaling or dialing are required.
7. The basis for an automatic circuit failure alarm is provided.
8. A simple method of modulation, without use of transformers, is made possible.
9. Installation, testing, and maintenance are greatly simplified.

To obtain these advantages and, at the same time, to avoid, or at least minimize, the difficulties which may arise from the transmission of several carrier frequencies at relatively high levels, particularly careful attention must be given to many problems in engineering design.

In the case of the type-*5* stackable 1-, 2-, or 3-channel carrier system described here, the manner in which some of these problems were solved may be of interest.

The carrier frequencies were chosen in such a manner that any sum or difference frequency which might be generated would fall outside of the carrier bands and outside of the normal telephone voice-frequency range. These carrier frequencies are 7.150, 10.725, 14.300, 21.450, 28.600, and 35.750 kc. The upper sideband is transmitted with the 14.300-kc carrier while the lower sideband is employed with all of the others.

Exceptionally good frequency stability is attained through the use of stabilized toroidal inductors with very low negative-coefficient ceramic capacitors in suitable circuits. Final frequency adjustment is made with a small air-dielectric variable capacitor.

Intermodulation is held to very low levels in the filters through the use, where required, of physically large low-permeability dust-core toroids or air-core inductors. The carrier-frequency repeating coil, which may be called upon to pass all transmitted and received carriers simultaneously, has a core of generous cross section built up with thin laminations of Mu-metal. When properly wound with sufficient turns of wire in each winding, a coil of this type maintains constant inductance over a considerable range of applied voltage and thus produces a minimum of intermodulation products.

To prevent crosstalk in the presence of transmitted carriers at relatively high levels, the band filters are designed to provide attenuations of 80 decibels or more, outside of the passband. Rejection notches are provided at the frequencies of other carriers which might be particularly troublesome if allowed to enter.

To minimize any possible interference with other carrier systems on the same pole line, the transmitted carrier frequencies of the type-*5* system can be partially suppressed at the transmitter and differentially amplified at the receiver. The addition of simple tuned circuits at each terminal makes this possible. Up to this time no necessity for this treatment has been encountered.

Physically, each terminal of this carrier system consists of panel mounted units assembled on a standard 19-inch rack. Rack space for a single channel terminal complete with signal unit and power supply is $22^{3}/_{4}$ inches. For the complete 3-channel terminal either $47^{1}/_{4}$ inches or $54^{1}/_{4}$ inches of rack space are required, depending on whether one or two power supply units are employed.

The first channel uses no power amplification and transmits at a maximum level of 10 decibels above one milliwatt. The second and third channels employ power amplifiers and are capable of transmission at levels up to 20 decibels above one milliwatt. The available over-all gain is approximately 23 decibels for the first channel and 35 decibels for the second and third channels. With these values of gain and transmission, performance, measured in miles of typical line, is approximately equal for the first and second channels, with the third channel dropping from 12.5 to 30 per cent.

Each of approximately 300 of these transmitted carrier systems, installed in various sections of the country, is giving satisfactory service with a minimum of maintenance.

Digest of paper 50-241, "An Improved Transmitted Carrier System for Telephone Lines of Short or Medium Length," recommended by the AIEE Committee on Wire Communication Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Tank Pressure Variation in Sealed Transformers

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IN A modern power transformer only the insulation, oil, and fibrous materials, show appreciable deterioration under normal operating conditions. Consequently, it is only natural that much effort has been applied to the problem of preventing or retarding this deterioration. Many schemes for this purpose have been devised; open air breather, dehydrating breather, conservators, gas-oil seals, sealed tanks, inert gas atmospheres, and thermosiphon clay filters are examples. These devices have one or two objectives: to prevent the entrance or to minimize the effects of moisture, or to exclude oxygen and minimize the effects of oxidation. The simplest and one of the most effective methods is to seal the transformer tank.

When a transformer is tightly sealed with a gas space over the top of the oil surface, it is subject to variation in internal pressure during its operating cycle. Changes in temperature due to ambient changes and to heating from excitation and load losses cause the oil to expand, and produce heating of the gas. Both effects result in an increase in internal tank pressure. The variation of pressure as a function of load and ambient temperature is of interest, both to transformer designers and operators.

The calculation of pressure as a function of load is not a simple one. The principal factors involved are: oil expansion due to heating, pressure temperature effects on gas, tank wall deflection, solubility of the gas in transformer oil, and chemical reactions between the gas and transformer oil. The effects of the first two of these factors may be easily and accurately calculated. Tank wall deflection is a relatively minor, though appreciable, factor, and it can be estimated empirically from test results with fair accuracy. Gas solubility and reaction with transformer oil are difficult to calculate, but they play the major role in determining transformer pressure.

Standard temperature run tests made on a 500-kva transformer gave data which lead to these conclusions:

1. With standard rectangular tanks the effect of tank wall deflection is to decrease the measured pressures below the calculated values by approximately 15 per cent.

2. With commercial methods of processing, a transformer, as delivered for use, will have a load pressure characteristic greatly different from that calculated by the gas laws. This is true whether the transformer is or is not filled under vacuum. In both cases, under rated load, the maximum pressure will be reached before constant temperature is attained and the pressure will be lower than that calculated by the gas laws. Vacuum-filled transformers have lower pressures than those which are not.

Digest of paper 50-275, "Variations of Tank Pressure with Transformer Loading in Sealed Transformers," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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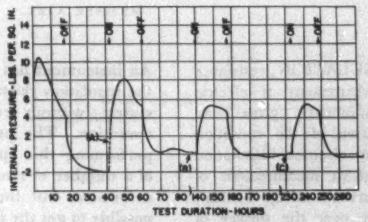

Figure 1. Time pressure curve. Oil filled under vacuum and sealed at atmospheric pressure. Repeated load cycles. Air in the gas space

3. When vacuum filled, if allowed to stand open for 24 hours before sealing, the results are about the same as when the transformer is sealed immediately. The gas does not quickly go into solution at ambient temperature with nonagitated oil.

4. As illustrated by Figure 1, in a vacuum-filled transformer the load pressure characteristic stabilizes after about one full load temperature test cycle. The average oil temperature varied from 20 degrees centigrade to 65 degrees centigrade and the transformer had a gas-to-oil ratio of 13.75 per cent.

5. After a transformer is vacuum filled, a considerable amount of gas must be added under pressure while the oil is hot before the oil becomes saturated with gas. In these tests, the oil dissolved about $12^1/_2$ per cent of nitrogen by volume corrected to 25 degrees centigrade and atmospheric pressure.

6. If negative pressures are to be avoided in sealed transformers, it is necessary to restore gas which is removed by vacuum filling of the transformer. This gas is not easily restored. One suggested method is to charge the gas space with dry nitrogen at a positive pressure of from six to eight pounds per square inch before it is placed in operation. This charge then should be repeated once or twice after the transformer has undergone a load cycle. This practice is safe only if the tank is protected with a relief valve set to operate at a pressure a little lower than the tank test pressure.

7. Another and simpler method of restoring gas to the oil is to provide the transformer with a relief valve to relieve excess external pressure. During normal operation, after a few temperature extremes, sufficient air is admitted to saturate the oil to the extent that thereafter no further adjustment will take place. The amount of oxygen admitted is too small to adversely affect the oil properties.

8. Once the oil is saturated with gas and sealed, the operating pressure range will be in the order of 80 to 85 per cent of that calculated by the gas laws.

Measurement of Insulation Resistance on Energized Systems

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An instrument has been developed to measure the insulation resistance of either an a-c or d-c system without removing the system from operation. The present voltmeter method of performing this operation involves the taking of a number of readings and applying these to a formula, but the new instrument makes it possible to get the information which is desired directly.

INSULATION resistance measurement of electric equipment gives an indication of the condition of the electrical insulation through a measurement of the current leakage through and/or over the surface of the insulation. These leakage currents are influenced by the dielectric state of the insulation and by the presence of moisture and other contaminants; therefore, a measure of the insulation resistance of electric equipment or of a system assists greatly in determining the safety and reliability of the equipment for operation.

The insulation of electric systems of vessels tends to deteriorate with time, owing to the abundance of moisture and salt that saturates the surrounding atmosphere. This tendency, if not checked, will result in establishing one or more low-resistance paths between the system and ground. This condition may endanger the operation of the electric plant, personnel, and possibly the safety of a ship when electrically propelled. Thus it is important that the system insulation resistance be observed continuously so that deterioration of insulation resistance can be checked to prevent the establishment of grounds.

This resistance can be easily and directly measured by a Megger or other suitable ohmmeters. Their use, however, entails the de-energization of the system during the period of measurements. It is evident that this procedure is not feasible generally and is impossible where continuity of service is necessary.

At present the voltmeter method is employed on energized d-c systems. This consists in measuring with a voltmeter of known internal resistance the system voltages from each line to ground, and across both lines. The three voltage readings and meter resistance are applied to a simple formula which permits calculation of system insulation resistance. This method suffers from a number of shortcomings, namely, involved procedure of multiple measurements and calculations, inaccuracies due to variation in system voltage while obtaining voltmeter readings, and insensitivity of the voltmeter when the insulation resistance is high. It is apparent that this procedure is laborious and indirect, and it does not provide the accuracy that can be obtained from measurements on de-energized systems.

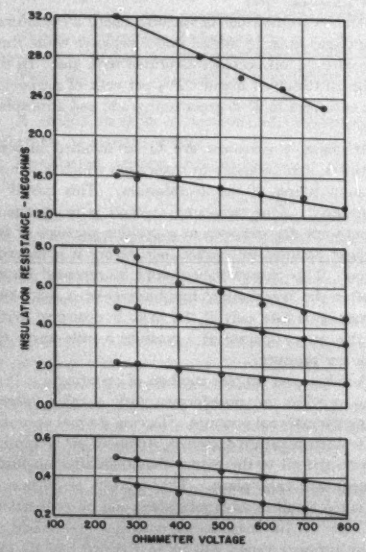

Figure 1. Effect of ohmmeter voltage on insulation

BASIC CONCEPTS

A CONSIDERATION of the problems involved with presently employed insulation resistance measuring devices on shipboard, an analysis of operational problems, and a study of insulation characteristics suggest that the requirements for a ground detector are that it shall contain its own source of voltage for stressing the insulation, and that it provides a direct reading with simplicity of operation.

The first requirement is satisfied by an electrically isolated rectifier-type power supply. The magnitude of its voltage should be approximately equal to the potential of the system to be measured. The importance of proper selection of this voltage has been demonstrated by S. Evershed[1] and is further illustrated in Figure 1. The

Full text of paper 501-94, "Measurement of Insulation Resistance on Energized Systems," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3-5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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influence of voltage, varying from 250 to 800 volts (ohmmeter open-circuit voltage), upon observed insulation resistance of electric systems ranging from 0.2 to 20 megohms is depicted. It becomes evident that the application of a voltage stress lower than the system normally experiences would result in an unrealistic measure of insulation resistance whereas the use of a voltage stress higher than system voltage may result in insulation breakdown.[2]

The second requirement can be met through the use of an ohmmeter type of instrument. Such an instrument could utilize a ratio-type meter movement, as employed in a Megger, or could consist of a constant-potential supply and a microammeter or a milliammeter with a scale calibrated for resistance. In order to employ such a device in a 2-wire ungrounded d-c system it is necessary to be able to select some point at which the potential of the ohmmeter circuit can be impressed on the electric system. This point must be selected so that no additional potential is injected into the measuring circuit.

The basic circuit for meeting this second requirement is illustrated in Figure 2. In this circuit R_A and R_B represent the distributed resistance of each line to ground for the associated circuit. The potentiometer connected between points l and m provides a means whereby a point of zero potential, namely that between G and S, can be obtained. This is obtained when the slider of the potentiometer is adjusted to give the relationship

$$\frac{R_x}{R-R_x}=\frac{R_A}{R_B} \qquad (1)$$

Thus a point of zero potential has been obtained for insertion of the measuring instrument. However, the presence of the potentiometer will cause an error as given by the equation

$$\text{Error in ohms}=\frac{R_x(R-R_x)}{R} \qquad (2)$$

where R is the total resistance of the potentiometer. It should be noted that this error is dependent only on the potentiometer and independent of the insulation resistance. If this error is expressed in terms of the fractional distance x of the slider from l it becomes

$$\text{Error}=x(l-x)R \qquad (3)$$

The relationship is plotted in Figure 3. (This applies only to a linear potentiometer.) It is evident from equation 3 that the error can be diminished by reducing the resistance value of the potentiometer; however, the reduction of this resistance is limited by the practical consideration of energy dissipation in the potentiometer. For example, on a 700-volt system a 10,000-ohm potentiometer rated 50 watts must be used. Since the reduction of potentiometer resistance to a very low value is impractical, compensation for the error was resorted to. The error, being a variable quantity, was not easily compensated alone. However, putting a second potentiometer in series with the balancing potentiometer produces a total error which is constant; that is, independent of slider position.

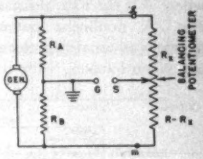

Figure 2. Basic circuit of the ground detector

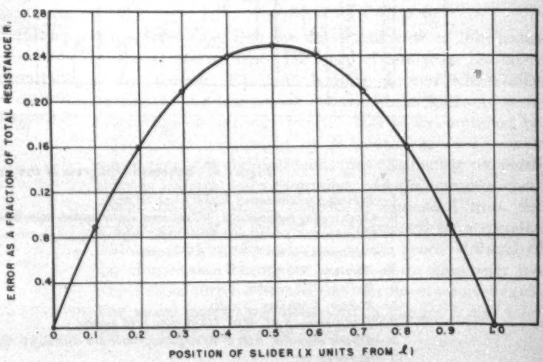

Figure 3. Error produced by a balancing potentiometer in the basic circuit

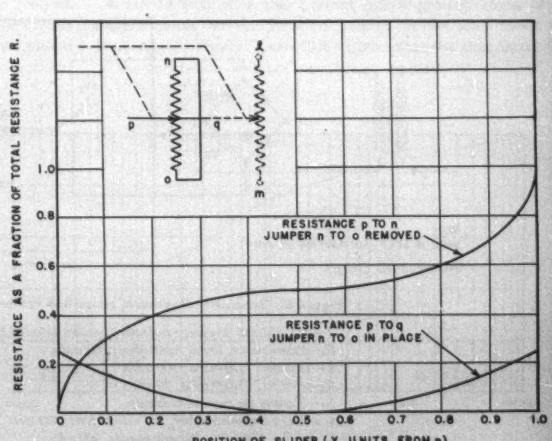

Figure 4. Characteristics of compensating potentiometer

This error then could be compensated by removing the corresponding amount of resistance from the internal circuit of the measuring instrument.

The resistance at the terminals of the compensating potentiometer, if R_{comp} is allowed to have its minimum possible value, must be given by the equation

$$R_{comp} = [0.25 - x(1-x)]R \qquad (4)$$

where R is the total resistance of the balancing potentiometer. A nonlinear potentiometer having this characteristic was connected electrically in series with the balancing potentiometer, with the shafts of the two potentiometers mechanically coupled. The characteristics of the compensating potentiometer and the connections are shown in Figure 4.

DESCRIPTION OF THE GROUND DETECTOR

It becomes evident that operation of a device employing the aforementioned principles requires (1) a circuit to detect the unbalanced voltage between the slider of the balancing potentiometer and ground, and (2) a means of driving the balancing potentiometer to the point of zero potential or null point. Two methods have been developed for performing this operation. The first utilizes a volt-

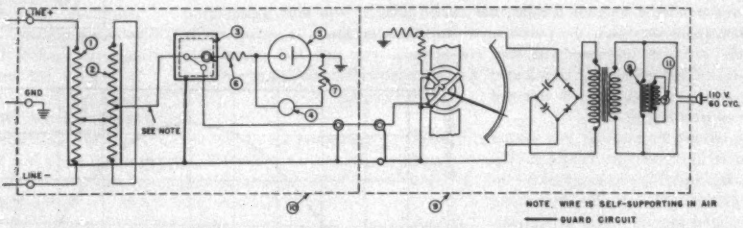

Figure 5. Schematic diagram of the ground detector

1—Balancing potentiometer, 10,000 ohms, 50 watts
2—Compensating potentiometer, 10,000 ohms, center tapped, taper wound
3—Galvanometer switch, push-button type, single-pole, single-throw. Normally closed on ohmmeter circuit
4—Galvanometer center "0", 50 microamperes
5—Neon tube, 115 volts, 2.5 watts
6—Resistor, 0.25 megohm, 3 watts
7—Resistor, 1 megohm, 2 watts
8—Transformer, NRL 4210, 115/6 volts, 0.15 ampere
9—500-volt ohmmeter, scale 0-10 megohms, calibrated with 2,500 ohms in the external circuit
10—Instrument box
11—Pilot light, Mazda 47, 6.3 volts, 0.15 ampere

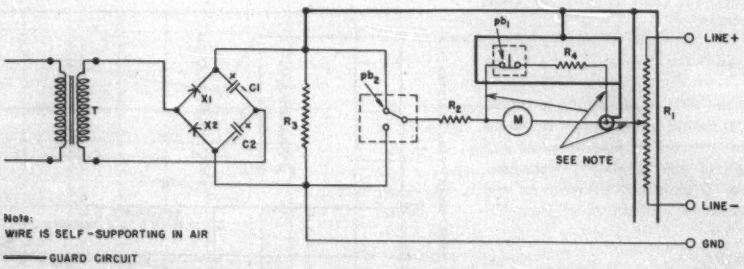

Figure 6. Schematic diagram of simplified version of the ground detector

T—115/230-volt 60-cycle transformer (constant potential type)
R_1—Potentiometer, linear, 5,000 ohms, 100 watts
R_2—Resistor, 5,000 ohms, 100 watts
R_3—Resistor, 25,000 ohms, 10 watts
R_4—Shunt to the ammeter resistance
x_1 and x_2—Dry-disc rectifier, 120 milliamperes, 500 volts
C_1 and C_2—Capacitor, 100 microfarads, 600 volts
pb_1—Single-pole single-throw switch, push button, normally closed
pb_2—Single-pole double-throw switch, push button, normally closed, on ohmmeter circuit

meter and manually controlled potentiometer. This system is illustrated in Figure 5. The detector circuit is designed to allow for observation of voltages as low as 0.25 volt, yet will not be damaged by voltages as high as several hundred volts. The ohmmeter, which is a rectifier-powered device, is normally connected between the compensating potentiometer and ground. By depressing switch 3, the operator can insert the detector, adjust the potentiometer to the null point, and then release the switch for observation of the insulation resistance as measured by the ohmmeter.

In another version of this principle, as shown in Figure 6, a d-c milliammeter, with scale calibrated for resistance, performs the dual function of ohmmeter and null detector. However, the resultant advantage of simplicity and fewer components is offset by the increase in insulation stress resulting from this circuit. This point is further clarified in a subsequent section of this article. Furthermore, such a scheme would require provisions for a constant potential at the output of the rectifier for any load current within the capabilities of the milliammeter. However,

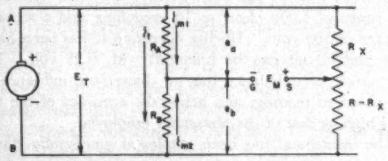

Figure 7. Leakage currents due to components of ground detector and system voltages

because of the possibility of zero- or low-resistance grounds existing, means must be provided for protecting the circuit against excessive currents. This circuit has been simplified further by eliminating the error-compensating potentiometer, employed in the circuit of Figure 5, and by using a smaller (5,000 ohms) balancing potentiometer. This would introduce a maximum possible error of 1,250 ohms, but by proper calibration of the milliammeter it can be reduced to ±625 ohms. This potentiometer would necessitate the dissipation of approximately 100 watts for a 700-volt system as compared to 50 watts' dissipation of the corresponding potentiometer in the unit of Figure 5. If it is desired to record changes in insulation resistance, the balancing operation can be made automatic, servoactuated by the unbalance voltage. The automatic ground detector would then provide a continuous record of the system insulation resistance with brief interruptions only during balancing.

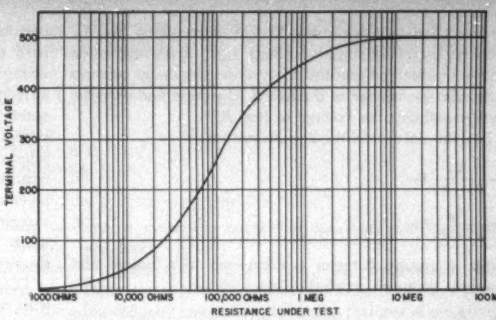

Figure 8. Voltage regulation at terminals of ground detector

GUARD SYSTEM

IT IS IMPORTANT that the use of this type of instrument should not influence the value of insulation resistance of the system. Thus, all leakage currents which may develop in the instrument due to dirt or moisture must by-pass the measuring circuit. This is accomplished by isolating or suspending in air all instrument wiring which is at a potential above ground, thus eliminating the possibility of leakage paths to ground. In the case of a component or wire which cannot be suspended thus, the leakage currents to ground are intercepted by a metallic plate or shield and conducted to the guard terminal of the ohmmeter. The guard system of the ohmmeter bypasses these currents around the instrument's current coil. The guard systems are illustrated in Figures 5 and 6 for the two described ground detectors.

SYSTEM STRESS

THE EMPLOYMENT of a ground detector on an energized circuit will alter the normal line-to-ground stress of system owing to the injected voltage of the ohmmeter. Referring to Figure 7, it will be noted that the magnitude of the insulation leakage currents to ground, normally i_1

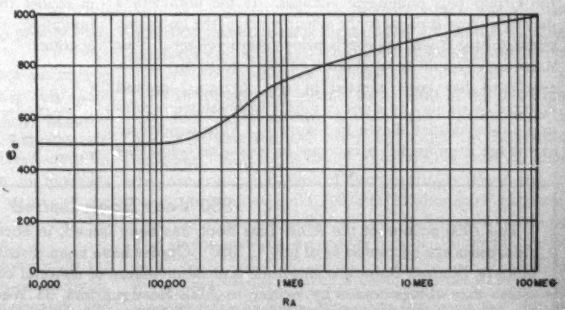

Figure 9. Possible maximum insulation stress on system, due to components of ground detector and system voltages

for each line, has been modified by currents i_{m1} and i_{m2} induced by the ohmmeter voltage E_M. From inspection it may be observed that the effect of the ohmmeter currents is to raise the voltage of the line A to ground and decrease correspondingly the voltage of line B.

In a normal system the line stresses are

$$e_a = \frac{R_A}{R_A+R_B} E_T \tag{5}$$

$$e_b = \frac{R_B}{R_A+R_B} E_T \tag{6}$$

When a ground detector is connected to a system and properly balanced so that

$$\frac{R_A}{R_B} = \frac{R_z}{R-R_z} \tag{7}$$

the corresponding stresses of equations 5 and 6 become

$$e_a = \frac{R_A}{R_A+R_B} E_T + \frac{R_A+R_B}{R+R_A+R_B} E_M \tag{8}$$

$$e_b = \frac{R_B}{R_A+R_B} E_T - \frac{R_A+R_B}{R+R_A+R_B} E_M \tag{9}$$

Owing to the fact that the value of R is very small for magnitudes of R_A and R_B greater than one megohm, these relations may be simplified as follows:

$$e_a = \frac{R_A}{R_A+R_B} E_T + E_M \tag{10}$$

$$e_b = \frac{R_B}{R_A+R_B} E_T - E_M \tag{11}$$

where

E_T = system voltage
E_M = ohmmeter voltage of the ground detector
e_a = voltage from Line A to ground
e_b = voltage from ground to Line B
R_A = insulation resistance to ground of Line A
R_B = insulation resistance to ground of Line B
R = total resistance of balancing potentiometer (10,000 ohms in the subject instruments)
R_z = potentiometer resistance from slider to line at balance

Consideration of equations 10 and 11 reveals that as the insulation resistance of Line B is reduced to zero, the voltage to ground of Line A approaches in magnitude the sum of the system plus ohmmeter voltages. If the ohmmeter's driving voltage is equal to the system voltage, the insulation stress of Line B will approach twice system voltage. This stress could result in breakdown of the insulation. However, this has been averted in the developed ground detector by employing a power supply with voltage regulation characteristics shown in Figure 8. Thus a decrease in voltage accompanies a decrease in resistance below one megohm; this results in the driving voltage adapting itself to the condition of the insulation. The maximum voltage that can be experienced by a 500-volt system under any condition may be observed in Figure 9. It is to be noted that for the higher values of insulation resistance the system stress can go above 500 volts. However, a consideration of the values of insulation resistance and the required ratios of the resistance for each line to ground reveals that it is highly improbable for the system to experience voltages from 750 to 1,000 volts. Furthermore, when these conditions are established the insulation resistance is sufficiently high to withstand the stress.

The ground detector of Figure 6 requires a power supply with no voltage regulation if the calibration of the ohmmeter is to be independent of internal leakage currents through the guard circuit. However, if the power supply is designed with sufficient voltage regulation to avoid overstressing of insulation at low values of resistance, it will result in inaccuracies when measuring in the range of approximately 0.1 megohm and above. This inaccuracy is attributed to guard circuit currents affecting the voltage at the terminals of the ohmmeter.

RESULTS AND CONCLUSIONS

The instrument has been developed with a measuring range of 5,000 ohms to 10 megohms and a stressing voltage of 500 volts. During operation it has been found that null circuit can be balanced with 0.25 volt. This magnitude of unbalance has no discernible influence on the observed reading, and hence the accuracy of the unit is as high as that of the ohmmeter employed.

The instrument has been employed successfully during the major part of the year to measure insulation resistance over a wide range of system voltages on direct as well as alternating currents. Periodic calibration has indicated that the instrument retains its accuracy and that the performance is stable and thoroughly reliable.

This instrument can be employed to measure accurately the insulation resistance of any ungrounded d-c or a-c system whether energized or nonenergized. It contains its own source of electromotive force for stressing the insulation to its rated voltage but with such regulation as to render the stress proportional to the condition of the insulation. The unit is direct reading and simple to operate.

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1950 Year Book Issued

The 1950 edition of the AIEE Year Book has been issued, in accordance with 1949–50 budget provisions. Addresses are corrected as of July 1, 1950. Copies have been distributed to all national, District, and Section officers, Student Branch counselors, and all members of national committees. Fellows, Members, and Associates may obtain copies by writing to AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. The Year Book is not available to nonmembers of AIEE; nor is its use permitted for commercial, promotional, or circularization purposes.

Totally Enclosed Auxiliary Drive Motors for Generating Stations

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BECAUSE OF certain developments in the design of equipment for central stations and because of changes in the general economic conditions, the performance and reliability of essential auxiliary drive motors has become increasingly important. A reassessment of the requirements for such motors and a discussion of their economic justification therefore appears to be in order.

The major developments which have occurred over the last 10 to 15 years are as follows:

1. Boiler and turbine inlet steam pressures and temperatures have risen steadily. As ever higher steam pressures were applied, the unit principle of design gained the upper hand on economic grounds. With the unit principle of plant design, a greater premium has been thrust on improved reliability of the main components of the plant, such as boilers, turbogenerators, and the essential auxiliaries. With the unit principle of design, duplication of equipment in the form of operating reserve for the major, essential auxiliaries is either held to a minimum or avoided altogether, thus further accentuating the need for their greater reliability.

2. Toward the end of World War II and for several years thereafter, electrical utility systems have had to operate with a minimum of spare capacity. The experiences gained through such operation and the development of statistical methods for the evaluation of spare capacity requirements are giving confidence in the operation of systems with a minimum of spare capacity. Another factor in these considerations is the present high cost of new plant installation.

In the past seven years the Consolidated Edison Company of New York, Inc., has purchased 580 totally enclosed fan-cooled motors with an aggregate rating of 52,000 horsepower for major auxiliary application in new plant installation. It has been possible to justify the higher cost of totally enclosed motors on the basis of reduced maintenance and greater reliability.

Because of the lowered amount of spare or reserve capacity available today, it is natural that this spare capacity should lie in units of the oldest, least economical types. Therefore, the incremental heat rate incurred with the outage of a modern unit is high and reflects in an important manner on the cost assignable to auxiliary equipment when such equipment is the cause of the outage. Together, these factors put further emphasis on the reliability of station auxiliary equipment.

3. Labor wage rates have more than doubled in the last ten years without a significant increase in productivity. This, in turn, means that the cost of maintenance and repair has increased similarly. This condition puts a high premium on that kind of equipment which requires only a minimum number of operating and maintenance personnel.

When, after the last war, the Consolidated Edison Company of New York faced the necessity of major generating capacity expansion, the design features of the auxiliary drive motors were carefully studied in view of these general considerations and in view of accumulated operating experience.

EXPERIENCE

WITH increasing fuel costs, the development of highest temperature and corresponding highest pressure steam-generating equipment received new impetus. The development of such equipment in the largest possible capacities has not proceeded without the customary growing pains. The tightening up of spare or reserve capacity has resulted in higher loading of equipment for longer periods of time. Both of these factors have operated to disclose increased hazards.

Case 1. At one of the major stations, early one morning in December 1943 with the outside temperature below freezing and with a strong northwest wind blowing, a load swing of undetermined origin occurred, causing the safety valves of all boilers in operation at the time to blow off for several minutes. This strong wind caused the steam, escaping from the safety valves, to be driven back into the upper portions of the boiler room where the forced and induced draft fans are located, condensing on the relatively cold surfaces of the building and on the windings and frames of motors. The operators, being handicapped by the dense fog, could do nothing to shut off electric equipment in the affected areas. As a result of the condensation, two 200-horsepower 3-phase 2,300-volt commutator motors driving induced draft fans failed in their stator windings; four rotor circuit transformers used on these commutator motors flashed over internally (these are dry type); and one 3-speed 1,200/600/200-horsepower squirrel-cage induction motor flashed over in its stator windings. The station suffered a capacity loss of 100 megawatts for

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several days. The motors involved in these failures were open-frame dripproof types.

Case 2. Another major station has eight boilers with an equivalent capacity of 506 megawatts, operating at 1,200 pounds per square inch gauge and 900 degrees Fahrenheit. This installation was made between 1938 and 1941, and it was at that time a pioneering venture. Since 1944 this station has experienced three boiler tube failures where the steam escaped into the boiler room. Each of these cases resulted in the loss of one of the major auxiliary drive motors, such as forced- or induced-draft fan motor. Because this station is designed on the unit principle and without duplication of the auxiliary equipment, the auxiliaries for each boiler are supplied from a single 2,300-volt load feeder, so that the failure of any one motor on this feeder trips it out, de-energizing all the remaining equipment on the same feeder. It is believed that this feature was responsible for holding the loss down to a single motor in each case. On one of these occasions insulation resistance measurements were made on all of the motors in the exposed area within a half-hour after the boiler tube failure. These showed in each case that the insulation resistance had dropped to less than 10,000 ohms. At that time four 600-horsepower forced- and induced-draft fan motors and two 1,500-horsepower boiler feed pump motors were involved. All of these were open-frame dripproof types. In two of the cases of boiler tube trouble the associated motor failures occurred on the auxiliaries of the same boiler. In the third case, the escaping steam caused the forced-draft fan motor of an adjacent boiler to fail, resulting in the outage of two boilers. This is a serious situation in a unit type of plant, where one of the basic assumptions justifying that particular design is that the failure on one unit will not cascade to another.

Case 3. At a third station, which is an integrated type of plant, each main generating unit is supplied from four boilers, all of which are tied to a common steam header. For the two 160,000-kw units the 16 induced-draft fans, driven by 3-speed 1,000/450/150-horsepower motors, are located in a common roof monitor above the main roof of the boiler house. Immediately below the grating floor of this roof monitor are two 24-inch 400-pounds-per-square-inch-gauge-pressure main steam headers, one on each side.

In December 1945, a feed-water regulator failed, allowing one boiler to fill completely and overflow into one of the main steam headers. The sudden chilling of this steam line caused a flange gasket to blow out, leaving a 1/8-inch-by-8-inch opening discharging superheated steam into this area. Because of the time of the year, most of the windows were closed so that the escaping steam was largely confined within the room. Again, because of the dense fog, the operators were handicapped in their attempt to shut down equipment. Within minutes, 9 of the 16 1,000-horsepower induced-draft fan motors flashed over in one or both of their windings. The failure of these motors resulted in a loss of 300 megawatts of station capacity, and although it was possible to restore 200 megawatts the same day by operating five of the motors on the undamaged windings, all nine had to be rewound eventually. Here again, the motors were open-frame dripproof type.

Case 4. When, in the beginning of 1943, the station in case 3 had to be loaded to its full capacity because of increasing area loads and because of the addition of the load of an aluminum reduction plant, a series of winding failures developed in six of the motors that were involved in case 3. These failures were caused by erosion of the winding insulation through a sand-blasting effect of cinder-contaminated air.

The excessive amount of cinders came from a large number of otherwise insignificant leaks in the fan housings and duct work of the induced-draft fans. Because of high loads on these boilers, the flue gas pressures at the base of the smoke stack, in the duct work, and in the fan housings, rose above atmospheric pressure causing the excessive discharge of cinders. It took several months to locate and repair these leaks, but in the meantime the six motor failures could not be avoided. As stated in case 3, these motors were open-frame dripproof type.

Case 5. Through a study made over a 5-year period, from 1936 to 1941 inclusive, on the causes of failures of motors of 50 horsepower and larger in size, it was disclosed that out of 188 failures 35, or 18.6 per cent, were caused by water from broken pipes, fittings, leaking gaskets, leaking stuffing boxes on pumps, and so forth, entering the motors. All of the motors involved were open-frame dripproof design.

Case 6. At the station of case 1, there are four boilers which are equipped with mill and mill blower motors of totally enclosed fan-cooled design. These motors are located almost directly under the boilers. All four of these boilers are of the slag-bottom type which means that, in operation, the floor of the boiler combustion chamber is a pool of liquid slag with a temperature in excess of 2,000 degrees Fahrenheit.

On at least six occasions the molten slag has broken through the chrome ore bottom of the boilers, spilling over motors and mills. Whenever this happens, the operators attempt to stop the flow of molten slag by chilling the area of the leak with streams from fire hoses. In this process, the motors are often drenched with salt water. Although there are 32 motors in the area subjected to these conditions, there has been only one motor failure and that occurred when the specific motor was completely submerged in the molten slag. At least nine of these motors would have failed because of hot slag and salt water drenching if they were not the totally enclosed type.

MAINTENANCE

In all of the stations of the Consolidated Edison system, motor maintenance is carried out on the basis of schedules, subject to modification and revision as operating practices vary. These schedules take into account the divergent degrees of exposure hazards and they are coordinated with the schedules for outages of related major equipment, such as boilers or turbogenerator sets. Two types of maintenance operations are involved: (1) inspection and cleaning, and (2) overhaul.

An inspection and cleaning operation on open-frame motors consists of an inspection of windings, bearings, squirrel-cage bars, short-circuiting rings, rotor fans, and so forth, as far as these items are visible without dismantling of the motor. The cleaning consists of blowing out of the windings and frame pockets with compressed air at moderate pressure.

An overhaul consists of dismantling the motor by removing the bearing brackets and withdrawing the rotor. The windings are carefully inspected for looseness in the slots or at the winding supporting rings. Any worn spots on the windings are repaired and loose winding support cording is replaced. Generally the windings are given a coat of insulating varnish after they have been thoroughly cleaned. The bearings are checked and rebabbitted or replaced, as required. The bearing brackets are cleaned and the bearing housings are washed out to remove all accumulated sludge. The squirrel-cage bars and connections to the short-circuiting rings are inspected for cracks or broken welds. Shaft seal drains and labyrinths are inspected and cleaned. Insulation resistance and dielectric tests are made.

The frequency and per-unit costs of maintenance for open-frame dripproof motors and for totally enclosed motors have been obtained from three of the major generating stations of the Consolidated Edison Company. The frequency of maintenance work is shown in Table I.

Table I. Maintenance Periods for Open-Frame Motors

	Inspection	Overhaul
Forced-draft fan motors	1 month	2–4 years
Induced-draft fan motors	1 month	1–4 years
Boiler feed pump motors	1–3 months	2–5 years
Mill motors	1–2 months	1–2 years
Typical pump motors	1–3 months	1–4 years
Miscellaneous auxiliary motors	1–3 months	1–5 years

On totally enclosed motors inspections are not made. Although the experience with totally enclosed motors is limited, it appears that routine overhauls may be dispensed with. The maintenance work on this type of motor is expected to consist of infrequent repairs as may be required, occasional air gap measurements to determine bearing wear, and lubrication. This is borne out by the following experiences.

The earliest installation of a totally enclosed motor, consisting of a group of 16 mill and mill blower motors of 150-horsepower and 75-horsepower rating, respectively, was made in 1929. These motors are equipped with antifriction bearings and experience has shown that the bearing life is 15,000 to 20,000 hours. Therefore, these motors are dismantled every two years for the installation of new bearings. Except for one failure, previously mentioned, this scheduled replacement of bearings has been the only reason for overhauling the motors to date.

Another group of totally enclosed mill and mill blower motors of 100-horsepower rating was installed in 1946. This is the same group of motors discussed in case 6. In this group there has been only one failure, caused by a clamping finger of the rotor core laminations breaking off and cutting into the stator winding. This occurred in 1947, after approximately one year of operation. Because of that failure, the other 15 motors were disassembled to permit placing additional spot welds on the clamping fingers. No other maintenance work was done at that time. Since then no maintenance work, except lubrication, has been done nor is any contemplated in the near future. These motors have sleeve bearings.

Backed by the experience on these two groups of totally enclosed motors it is expected that no maintenance work, other than lubrication, will be needed. Although a considerable number of totally enclosed motors have been installed within the last two years, the experience with these, while entirely satisfactory to date, is evidently of too short duration to permit reaching a definite conclusion.

Since a considerable factor in the justification of totally enclosed motors lies in the expected maintenance savings, careful attention must be given to design and factory workmanship so that the anticipated savings can actually be realized.

ENCLOSURE TYPES

With the background of experience related in cases 1 to 6 and combined with the further knowledge that moisture proofing by means of varnishes (except perhaps silicone varnishes) will not protect windings against condensing steam or water, particularly after some years of operation, there arises the question as to what type of enclosure will eliminate these types of failures.

In attempting to answer this question consideration might be given to these enclosure types:

1. Splashproof.
2. Enclosed pipe-ventilated or base-ventilated.
3. Totally enclosed fan-cooled, water-cooled, or pipe-ventilated.

The splashproof enclosure, although it would effectively eliminate the hazard of dripping or splashing water, will not solve the steam condensation or excessive dirt problem. The enclosed pipe-ventilated or base-ventilated motor, when supplied with clean air free from snow or fine rain, should eliminate not only the hazard of dripping or splashing water but the hazard of steam and dirt as well. The difficulty is, however, that the procurement of clean air free from snow or fine rain requires the use of filters and, in most cases, long ducts which, in turn, necessitate the installation of separate motor-driven blowers, thus adding to installation and maintenance costs.

The totally enclosed motor alone seems to meet all of the requirements with respect to protection against all of the hazards previously discussed. On the Consolidated Edison system, the fan-cooled form has been the only one purchased to date. In a number of cases economic studies have been made comparing the over-all costs of fan-cooled, water-cooled, and pipe-ventilated enclosures, and even though ambient temperatures were as high as 55 degrees centigrade, requiring winding insulation of class *B* or *H*, the fan-cooled enclosure has proved most economical. This is the case also for water-cooled motors which, because of restrictions in the use of city water for cooling purposes, require the installation of additional heat exchangers to

salt water, with additional pumps and oversize equipment (the salt water temperature reaches 85 degrees Fahrenheit in the summer). For pipe-ventilation schemes the location of the motors usually dictates long and complex duct systems to insure a continuous supply of sufficiently low-

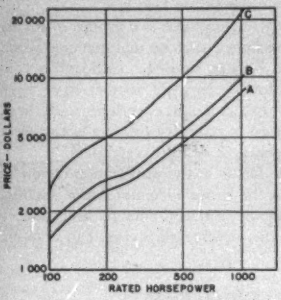

Figure 1. Price versus horsepower rating for 1,200-rpm class-A insulated motors. (A). Open-frame dripproof motors, 40-degree - centigrade rise. (B). Splash-proof motors, 50-degree - centigrade rise. (C). Totally enclosed fan-cooled motors, 55-degree centigrade rise

temperature air. Invariably the cost of such duct work exceeded the increment in motor costs for class-*B* or -*H* insulation at 55 or 75 degrees centigrade rise, respectively.

Table II. Standard Limits of Observable Temperature Rise of Machine Windings

	Temperature by Thermometer, Degrees Centigrade	Temperature by Resistance, Degrees Centigrade
General Purpose Motors		
Insulation class *A*	40	50
Insulation class *B*	—	—
Totally Enclosed Motors		
Insulation class *A*	55	60
Insulation class *B*	75	80
Other Types of Motors		
Insulation class *A*	50	60
Insulation class *B*	70	80

Table III. Limits of Observable Temperature Rise of Machine Windings

Insulation	Temperature by Thermometer, Degrees Centigrade	Temperature by Resistance, Degrees Centigrade
Class *B*	55	60
Class *H*	75	80

INSULATION CLASS AND TEMPERATURE RISE

INDUSTRY STANDARDS[1] give permissible limits of observable temperature rise for motors which are shown in part in Table II.

The National Electrical Manufacturers Association Standards[2] recognize a service factor of 1.15 for 3-horsepower and larger motors of the general-purpose type with class-*A* insulation and 40-degree centigrade temperature rise rating. Although the standards are not explicit in this respect, it is generally understood that such motors, when carrying continuously the load permitted by the service factor, will have a temperature rise not exceeding 55 degrees centigrade by thermometer.

Considering that, when motors are not exposed to unusual hazards, the experience with general-purpose motors, rated and applied in accordance with the cited standard,[2] is vast and generally satisfactory, it can safely be stated that these standards, in so far as they apply to general-purpose motors, were wisely chosen. It appears important then that a service factor be available as a safety factor, or ignorance factor, for totally-enclosed motors to allow for divergencies in ambient temperature and in loading. Thus, even with an ambient temperature 15 degrees centigrade in excess of 40 degrees centigrade, or a load 15 per cent in excess of nominal rating, the motor still will operate within the limits permissible for its insulation and therefore will have an acceptable life.

In the application of motors to power plant auxiliary drives, it is rarely possible to predict accurately the ambient temperature or to be certain that it will not exceed 40 degrees centigrade, particularly for forced-draft fans, induced-draft fans, mills, and other boiler auxiliaries. In addition, it frequently is found that the loads imposed on motors may exceed the anticipated load because of contingency operating conditions or because of variations in operating procedure. It is very desirable, therefore, that such a service factor, which is available only on general-purpose motors with 40-degree centigrade rise ratings, be obtainable in some way on motors with more complete enclosures. Such a service factor, safety factor, or ignorance factor, as the case may be, becomes available when totally enclosed motors are purchased with class-*B* or class-*H* insulation and with temperature rises as shown in Table III.

If a service factor of 1.15 is allowed on the basis of the temperature rises in Table III, the respective recognized limits for class-*B* or class-*H* insulation will not be exceeded.

COSTS

FIGURE 1 shows the relation between the prices and ratings of open-frame dripproof motors, splashproof motors, and totally enclosed fan-cooled motors. These are based on the prices of standard-temperature-rise motors having class-*A* insulation and were prepared from catalogue base prices and catalogue listed modification prices which were in effect on May 1, 1950.

The reason for basing the curves on 1,200-rpm class-*A* insulation motors only is to illustrate the effect on prices of the different enclosures and frame sizes without regard to other features.

The increase in price for class-*B* insulation for a 55-degree centigrade rise ranges from approximately 7.5 to 25 per cent above the base price for class-*A* insulation and depends on the motor horsepower rating and speed with the larger value corresponding to the lower speed. For class-*H* insulation, 75-degree centigrade rise motors, there is generally a 10-per cent increase in price over the class-*B* 55-degree centigrade rise motors, although in the larger sizes equal prices occasionally are quoted.

A considerable number of economic studies have shown

that the increased cost of totally enclosed motors is justifiable up to approximately 250 horsepower on the basis of maintenance savings alone. An outage of a motor up to this horsepower rating seldom involves the loss of a main unit, and therefore no considerable additional credit can be assigned on the basis of increased reliability.

For motors above 250 horsepower the difference in price between open-frame dripproof and totally enclosed motors increases at a greater rate than the evaluated difference in maintenance costs. However, an outage of a motor rated 250 horsepower and above generally involves a main unit, and the higher cost of the totally enclosed motor is justifiable on the basis of increased reliability in addition to the savings in maintenance costs. The loss of capacity factor and the incremental heat rate cost may outweigh all other factors for the larger auxiliary drive motors as for circulating water pumps, forced- and induced-draft fans, and boiler feed pumps.

Whether or not the purchase of totally enclosed motors can be justified depends on the type of design of the plant and on the degree of reliability which is expected. The adoption of the unit type of plant design, the extent to which duplication of auxiliaries is provided, and the amount of reserve capacity available to the system obviously will influence the decision.

On the Consolidated Edison system it generally has been found that for essential auxiliaries in power plants totally enclosed motors can be economically justified. On this basis a total of 580 totally enclosed motors with an aggregate rating of 52,000 horsepower has been bought since 1943.

It appears reasonable to expect that a thorough investigation of all of the factors entering into the design of auxiliary power drives and their comparative evaluation will disclose that totally enclosed motors may be economically justifiable to a greater extent than in the past.

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Electrical Essays

Motionally Induced Electric Fields—Part IV

Motional Electromotive Force in Iron, Commutatorless D-C Motor, and Space Ship

Jack, the physicist, is continuing his lectures to Alter Ego and his friends on the basic principles underlying dynamo-electric machines.

Jack: "We now have the universal equation for the motional electric field, $\mathbf{E}_{mot}$, induced in any honest-to-goodness body moving with a velocity $\mathbf{v}$ in a magnetic field $\mathbf{B}$, namely

$$\mathbf{E}_{mot}=\frac{1}{c}[\mathbf{v}\times\mathbf{B}] \tag{1}$$

This universal equation is consistent with the principle of energy, for if $\mathbf{i}$ is the current density in the body, we will have

$$P_e=\mathbf{E}_{mot}\cdot\mathbf{i}=[\mathbf{v}\times\mathbf{B}]\cdot\mathbf{i}=\mathbf{v}\cdot[\mathbf{B}\times\mathbf{i}] \tag{2}$$

$P_e=c\mathbf{E}_{mot}\cdot\mathbf{i}$ is the electric power supplied per unit volume by the moving body external circuit.

"We find the mechanical power by means of the universal equation

$$\mathbf{F}_m=[\mathbf{i}\times\mathbf{B}]=-[\mathbf{B}\times\mathbf{i}] \tag{3}$$

which gives the mechanical force, per unit volume $\mathbf{F}_m$, which the magnetic field $\mathbf{B}$ exerts upon any body carrying a current density $\mathbf{i}$. The mechanical power, per unit volume, which the moving body delivers to other bodies is then

$$P_m=\mathbf{v}\cdot\mathbf{F}_m=-\mathbf{v}\cdot[\mathbf{B}\times\mathbf{i}] \tag{4}$$

"Combining equations 2 and 4 we have

$$P_e+P_m=0 \tag{5}$$

That is, if the moving body is delivering electric power, as in a generator, then equal mechanical power must be supplied to it, and if the body is receiving electric power by $\mathbf{i}$ flowing against $\mathbf{E}_{mot}$, as in a motor, then it will deliver an equal mechanical power. Universal equations 1 and 3 are entirely in order as far as the principle of energy is concerned.

"But now, Alter Ego has something to say."

Alter Ego: "I am very glad to learn of the universal validity of equations 1 and 3 because based on them I have made two very important inventions; namely, a commutatorless d-c motor or generator, and a d-c driven space ship. I won't go into the details of these inventions, but will limit myself to describing their basic principles.

"Go back to the slide-wire experiment, Figure 1, and consider what will happen if the slide bar is a cylinder of very high permeability iron. The lines of force of the otherwise uniform magnetic field $\mathbf{B}$ will converge as is shown in Figure 2, and $\mathbf{B}$, within the circular section iron bar, will have almost twice the strength which it would have in a similarly placed copper bar. Therefore, according to your universal equation 1 which you say is absolutely right, the motional field $\mathbf{E}_{mot}$ in the iron bar will be twice what you would get for a copper bar.

"Now for my invention. Make a coil like I show in Figure 3, with two parallel sides, but make one of these

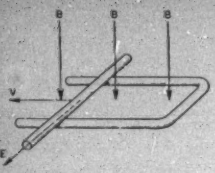

Figure 1 (above). The slide-wire experiment

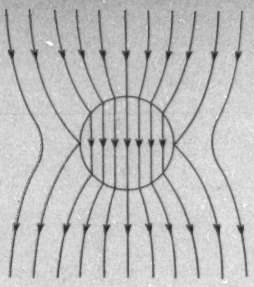

Figure 2 (right). Converging field in iron cylinder

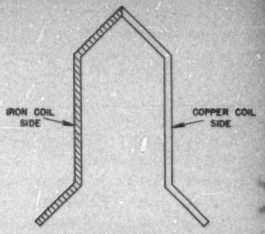

Figure 3. Iron-copper coil

parallel sides of iron and the other of copper. Now translate the coil in the magnetic field. There will be motional fields induced in the coil sides. If the coil had been all copper, then the motional field $\mathbf{E}_{mot}$ in the one coil side would oppose and just cancel the motional field $\mathbf{E}_{mot}$ in the other coil side, so far as the production of a total electromotive force around the coil is concerned. However, with one coil side iron, the motional field $\mathbf{E}_{mot}$ in it will be twice the motional field in the other side, copper coil, and these motional fields will not cancel round the coil, but the coil will give a net, not zero, electromotive force as it is moved in the uniform magnetic field. It is easy to see how we could mount a lot of these coils in series on a rotating member with slip rings, in a uniform magnetic field, and get a beautiful constant d-c voltage. There's your commutatorless d-c generator.

"Now, consider what happens if I send current through my (patent-pending) iron-copper coil while it is in a uniform magnetic field. If the coil had been all copper, then, according to your universal and absolutely right equation 3, the forces exerted by the magnetic field on the coil sides would be equal and opposite and would exactly cancel. However, in my iron-copper coil, the field **B** in the iron side is twice what it is in the copper side, and therefore, according to your universal equation 3, the force on the iron side will be twice the oppositely directed force on the copper side, and I will get a net force tending to move the whole coil. If I arrange a lot of these coils around on a rotor as in my generator, I'll get a commutatorless d-c motor. However, if I lay the coils out in a plane, I'll get a space ship, since the reaction on the field-producing member will be the same as if the coils were all copper, namely, zero. Aren't those wonderful inventions, Dr. Jack?"

Jack: "I don't like to throw cold water on your enthusiasm, Alter Ego, but I doubt that your inventions will work. You will remember that in my last lecture (*EE, Jan '51, pp 67–68*), I showed that the sum of all the electric fields, the electrostatic, that induced by transformer action, and the motional, when integrated round any closed material circuit, was equal to $1/c$ times the rate of change of the integral of **B** over any surface enclosed by the circuit, or in other words, to $1/c$ times the rate of change of the total flux linked by the circuit. Now, as your coil moves in the uniform magnetic field, the amount of flux linked by it does not change. Therefore, the total current-producing electromotive force which is around your coil stays zero.

"Of course, you should have obtained the same result using the motional equation 1, but you did not. Some people think that the **v** in equation 1 stands for the motion of the moving body, not relative to space or some suitable material frame of reference but relative to the magnetic field itself, and that where the field lines bunch up as in your iron bar the bar carries them along somewhat, so that the lines of force slide or cut through the bar with only half that velocity with which they are cut by the copper bar so that the motional field is the same in the iron as the copper. Maybe that is the way out. . . ."

I interrupt Jack at this point, because I am already behind in my reply to the preceding essay and I must catch up.

Will Jack be able to explain away the contradiction, along the line he has indicated? Watch for the next exciting episode in the next installment.

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Three Impedances

Three impedances are so proportioned that when connected in star and energized from a 60-cycle system

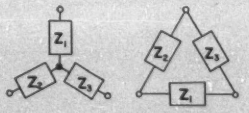

Figure 1. Star and delta connections of three impedances

they form a network that is equivalent to a network formed by the same three impedances connected in delta. Is this possible?

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Answers to Previous Essays

Correction to Motionally Induced Electromotive Force. The following is the author's correction to the Part II essay and the answer to Part I (*EE, Dec '50, pp 1086–9*).

The units used in these essays on "Motionally Induced

Electromotive Force" are Gaussian, that is, $\mathbf{E}$, $\mathbf{D}$, $\mathbf{P}$, ρ, and V are in centimeter-gram-second electrostatic units, and $\mathbf{H}$, $\mathbf{B}$, $\mathbf{M}$, and $\mathbf{i}$ are in centimeter-gram-second electromagnetic units. Other quantities such as $\mathbf{v}$, c, $\mathbf{F}$, and so forth, are in centimeter-gram-second units. With these units, $\mathbf{v}$ and c occur in all equations as the ratio $\mathbf{v}/c$. It seemed to the author that this relationship of $\mathbf{v}$ to c is worth emphasizing, and with these units the continual appearance of $\mathbf{v}/c$ gives this emphasis.

However, the author slipped from consistent adherence to these units in a few places in *Electrical Engineering*, December 1950. On page 1086, the lines following equation 7 should read, "where cVI is the electrical power input, cRI^2 is the Joulean heat developed, and $cV_eI=vIBl$ is the mechanical power, since IB is the force . . ."

On page 1089, column 1, line 17 from the bottom, the equation should read

$$4\pi\left(\mathbf{i}+\frac{1}{4\pi c}\frac{\partial \mathbf{D}}{\partial t}\right)=\text{curl }\mathbf{H}$$

instead of as given.

J. SLEPIAN (F'27)
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Motionally Induced Electromotive Force—Part III. The following is the author's answer to his previously published essay (*EE, Jan '51, pp 67–68*).

No, there is no motional field $\mathbf{E}_{mot}$ in vacuum or, for that matter, anywhere else, in the author's opinion. Having chosen a particular frame of reference in which Newtonian particle mechanics holds, or better yet, relativistic particle mechanics holds, then we may define $\mathbf{E}$ and $\mathbf{H}$ from the forces which we observe on small enough charged material probes placed at that point in empty space where we wish to observe $\mathbf{E}$ and $\mathbf{H}$. Then Maxwell's equations are found to hold for these vectors $\mathbf{E}$ and $\mathbf{H}$ thus defined in empty space. Within matter $\mathbf{E}$ and $\mathbf{H}$ are as yet undefined, since the operation of observing forces on a charged probe to be placed within matter has no meaning.

However, $\mathbf{E}$ and $\mathbf{H}$ are observable in empty crevices in matter, and if we assume that Maxwell's equations hold for $\mathbf{E}$ and $\mathbf{H}$ so observed in any and all the crevices which we can construct in the material body, then it follows that equations 1, 2, 3, and 4 given on page 1088 (*EE, Dec '50*) define vectors $\mathbf{E}$, $\mathbf{D}$, $\mathbf{H}$, and $\mathbf{B}$, which we call the electromagnetic field vectors for the material body.

The velocity $\mathbf{v}$ which enters into the definition of these field vectors is the velocity of the material of the body which bounds the crevice. If now we *define* the charge density ρ by the equation $4\pi\rho=\text{div }\mathbf{D}$, and the current density $\mathbf{i}$ by the equation $4\pi\left(\mathbf{i}+\frac{1}{4\pi c}\frac{\partial \mathbf{D}}{\partial t}\right)=\text{curl }\mathbf{H}$, then Maxwell's field equations will hold for all these quantities, thus defined ultimately by means of measurements of force on charged probes at rest or moving in empty space, and in some particular frame of reference.

Including ρ and $\mathbf{i}$, we have then five vector field quantities and one scalar field quantity which enter in Maxwell's field equations. These last are two vector equations which refer to curl $\mathbf{E}$ and curl $\mathbf{H}$, and two scalar equations which refer to div $\mathbf{D}$ and div $\mathbf{B}$. Maxwell's field equations are then not mathematically determinate, since they have more dependent variables than the number of independent equations.

To make a mathematically determinate system, we postulate that sufficient additional relations are imposed upon the field quantities by the material itself. These constitutive relations are dependent upon the nature of the material, and may be expected to vary with the pressure, temperature, and so forth, of the matter, possibly also with its past history, and, important for our present purpose, also with its velocity. These constitutive relations may be found by experiment, or may be deduced from theories of the microscopic structure of matter, and of the behavior of microscopic particles, electrons, dipoles, nuclei, and so forth. They are the data of Maxwell theory and not any part of the conclusions from Maxwell theory.

Maxwell's field equations are equivalent to six independent scalar equations, and the field quantities are equivalent to 15 independent scalar variables. To make a mathematically determinate system, the constitutive relations must then be equivalent to nine independent scalar relations.*

Thus for empty space we have $\mathbf{D}=\mathbf{E}$, $\mathbf{B}=\mathbf{H}$, $\mathbf{i}=0$, and $\rho=0$, which are equivalent to nine independent scalar equations. Again, for a nonmagnetic metal at rest we may have $\mathbf{i}=\sigma\mathbf{E}$, $\mathbf{B}=\mathbf{H}$, $\mathbf{D}=0$, $\rho=0$, again equivalent to nine independent scalar equations.*

The problem of the electromagnetism of moving bodies is thus reduced to the problem of determining what are the constitutive equations for the matter of bodies in motion. Is there some general method whereby from a knowledge of the constitutive relations for the material making up a body at rest, we may deduce the constitutive equations for that body in uniform motion with velocity $\mathbf{v}$?

Minkowski and Einstein described such a general method in 1905. Given a body at rest, for which constitutive equations connecting the field quantities $\mathbf{E}'$, $\mathbf{D}'$, $\mathbf{H}'$, $\mathbf{B}'$, $\mathbf{i}'$, and ρ' are known. Then if in these equations we substitute

$$\mathbf{E}'=\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]$$

$$\mathbf{D}'=\mathbf{D}+\frac{1}{c}[\mathbf{v}\times\mathbf{H}]$$

$$\mathbf{H}'=\mathbf{H}-\frac{1}{c}[\mathbf{v}\times\mathbf{D}]$$

$$\mathbf{B}'=\mathbf{B}-\frac{1}{c}[\mathbf{v}\times\mathbf{E}]$$

$$\mathbf{i}'=\mathbf{i}-\frac{1}{c}\rho\mathbf{v}$$

$$\rho'=\rho+\frac{1}{c}\mathbf{v}\cdot\mathbf{i} \qquad (1)$$

*Any vector equation may be written as the three equations between the component of the two sides of the equation. However, the three components of the curl of any vector $\mathbf{A}$ must not be regarded as independent since we have always the scalar equation div curl $\mathbf{A}=0$. Therefore, the equation of Maxwell referring to curl $\mathbf{E}$ must be regarded as equivalent to only two independent scalar relations, and similarly for the equation concerning curl $\mathbf{H}$. Also, the field quantities $\mathbf{i}$ and ρ must always satisfy the equation div $\mathbf{i}+\frac{\partial\rho}{\partial t}=0$. Therefore, $\mathbf{i}$ and ρ must be regarded as equivalent to only three independent scalar quantities.

we will get the constitutive equations for that body moving with uniform velocity $\mathbf{v}$.**

Let us apply this method to determine the constitutive equations for the moving glass rod of Alter Ego. For the rod at rest, we have

$$\mathbf{D}' = \epsilon \mathbf{E}'$$
$$\mathbf{B}' = \mathbf{H}'$$
$$\mathbf{i}' = 0 \qquad (2)$$

Substituting equation 1 we have the desired constitutive equations

$$\mathbf{D} + \frac{1}{c}[\mathbf{v} \times \mathbf{H}] = \epsilon\left(\mathbf{E} + \frac{1}{c}[\mathbf{v} \times \mathbf{B}]\right)$$

$$\mathbf{B} - \frac{1}{c}[\mathbf{v} \times \mathbf{E}] = \mathbf{H} - \frac{1}{c}[\mathbf{v} \times \mathbf{D}]$$

$$\mathbf{i} - \frac{1}{c}\mathbf{v}\rho = 0 \qquad (3)$$

If we neglect higher powers of v/c than the first, then equation 3 reduces to

$$\mathbf{D} = \epsilon \mathbf{E} + (\epsilon - 1)\frac{1}{c}[\mathbf{v} \times \mathbf{B}]$$

$$\mathbf{B} = \mathbf{H} - \frac{\epsilon - 1}{\epsilon}\frac{1}{c}[\mathbf{v} \times \mathbf{D}]$$

$$\mathbf{i} = \frac{1}{c}\mathbf{v}\rho \qquad (4)$$

Thus we see that Jack's guess at the constitutive equation of the glass rod, his equation 10 (*EE, Jan '51, p 68*), is wrong. Jack's motional field, $\mathbf{E}_{mot} = 1/c[\mathbf{v} \times \mathbf{B}]$ does not produce induction $\mathbf{D}$ like "any other field $\mathbf{E}_v$." Also we see from the second of equations 4 what Jack appears not to even suspect, namely that the glass rod which is nonmagnetic at rest will become magnetic, that is, $\mathbf{B}$ will not equal $\mathbf{H}$ for it, if it moves in an electric field $\mathbf{D}$.

The air in Alter Ego's inner tube will also have the constitutive equations 4, but as it is pumped out, ϵ will approach 1, and the constitutive equations will approach those for a vacuum, with $\mathbf{v}$ disappearing. There is then no motional electric field in a vacuum (or anywhere else for that matter).

Now that we have the constitutive equations for a glass rod, we may readily solve the problem of what will be the field in a glass rod moving in an otherwise uniform magnetic field. We shall do that in the reply to the next essay which will deal with a somewhat similar problem.

J. SLEPIAN (F '27)

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Reactive Power. The following is the author's answer to his previously published essay (*EE, Jan '51, p 68*).

The reactive power for the general case of an alternating current and an alternating potential difference where both have harmonics is the algebraic sum of the reactive powers corresponding to the sinusoidal harmonic components

$$Q = E_1 I_1 \sin \theta_1 + E_3 I_3 \sin \theta_3$$

For the networks submitted in the essay

$$\theta_3 = -\theta_1; \quad Z = \sqrt{R^2 + X^2}$$

and the reactive power may be written

$$Q = \pm \frac{E_1^2 - E_3^2}{Z}\sqrt{1 - \Delta^2}$$

from which the per-unit expression for reactive power is

$$Q' = \pm \frac{E_1^2 - E_3^2}{E_1^2 + E_3^2}\sqrt{1 - \Delta^2}$$

Computing rms voltages and currents in the elements of the network, the following is found to be the per-unit reactive power in the series network A

$$Q'_A = 1.25\,\frac{E_C^2 - E_L^2}{E_C^2 + E_L^2}\sqrt{1 - \Delta^2}$$

Similarly, for the network with a parallel connection of reactive elements B, the per-unit reactive power is

$$Q'_B = 1.25\,\frac{I_C^2 - I_L^2}{I_C^2 + I_L^2}\sqrt{1 - \Delta^2}$$

The correct sign of reactive power is given by the equations. It is possible to conceive a circuit of zero power factor and of zero reactive factor. In such a circuit the apparent power is entirely fictitious and is equal to the distortion power. This occurs when $R = 0$, and $E_3 = E_1$.

A. A. KRONEBERG (F'48)

(Southern California Edison Company, Los Angeles, Calif.)

Star or Delta? The following is the author's answer to his previously published essay (*EE, Jan '51, p 68*).

Impedances comprising both networks can be expressed in Heaviside operational form

$$Z_a = Lp; \quad Z_b = Z_c = R \qquad (1)$$

$$Z_B = Z_C = R + 2Lp; \quad Z_A = 2R + 1/Cp = 2R + R^2/Lp \qquad (2)$$

Using these values of impedances in equations for transformation from star to delta or vice versa, it can be demonstrated that the two networks are equivalent. When networks are equivalent when expressed in Heaviside operational form, they are networks of "general equivalence" as defined in American Standard Definitions of Electrical Terms:[1] "If one network can replace another network in any system whatsoever without altering in any way the electrical operation of that portion of the system external to the networks, the networks are said to be networks of 'general equivalence.'" When such networks are enclosed in similar containers and only their terminals are available for testing, it is impossible to determine by purely electrical measurements the nature of the network in each container.[2-3]

REFERENCES

1. American Standard Definitions of Electrical Terms. *AIEE*, Section 65.20.680, 1941, page 215.

2. Which Box Contains the Network? J. Slepian. *Electrical Engineering*, volume 67, December, 1948, page 1141.

3. Network, A. A. Kroneberg. *Electrical Engineering*, volume 68, November, 1949, page 984.

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** Equations 1 are not precisely the transformation equations of relativity theory as given by Einstein and Minkowski but differ by terms involving the second and higher powers of v/c.

INSTITUTE ACTIVITIES

Five Sessions Held at Conference on Electron Tubes for Computers

That a better exchange of ideas should exist between manufacturers of vacuum tubes and the designers of computer circuits was one of the main conclusions reached at the Conference on Electron Tubes for Computers. The conference was sponsored by the AIEE and Institute of Radio Engineers, in collaboration with the Panel on Electron Tubes of the Research and Development Board, at Haddon Hall Hotel, Atlantic City, N. J., December 11–13, 1950, and was attended by more than 300 engineers from all parts of the country and from as far away as Canada and England. A great deal of the credit for the success of the conference is due to Dr. C. V. L. Smith, head of the Computer Section, Office of Naval Research.

The need for this conference arose from the results of a survey conducted by Dr. A. L. Samuel, chairman of the Panel on Electron Tubes of the Research and Development Board of the Department of Defense, who noted indications that the field of electron tubes for computers was in need of clarification. The general chairman of the conference committee was Dr. Mina Rees, Office of Naval Research, who, in her opening address to the first session of the conference of which she was chairman, outlined the nature of the five sessions and what would be covered by the 31 papers presented. In addition to the exchange of ideas between tube manufacturers and users, she stated that the demand for tube reliability is paramount because "down time" due to tubes in computers is more or less intolerable when the cost of such installations and their operating costs are so high.

W. R. Clark, Leeds and Northrup Company, opened the first session, which was on computer experience with electron tubes. He reviewed the AIEE tube conference held in Philadelphia in 1948 and the one in 1949 at Buffalo, N. Y., at which tube manufacturers and their customers exchanged ideas that resulted in general improvements for both. The tube manufacturers were helped in their programs and they explained about the tubes which were marketed for instrumentation. The speaker also presented statistics concerning the tube consumption of 1950 over that of the previous year, which in several instances showed an increase of more than 100 per cent.

The next paper, "Experience with Receiving-Type Vacuum Tubes on the Whirlwind Computer Project," was given by E. S. Rich, Massachusetts Institute of Technology (MIT). He outlined the tests employed at MIT for various tube defects and the results obtained: many specific tubes for computers show a better performance over commercially available tubes, but the latter can be made to function satisfactorily if precautions are taken to avoid the use of circuits which demand performance beyond the tubes' capabilities.

J. A. Goetz and E. W. Brooke, International Business Machines Corporation, presented "Electron Tube Experience in IBM," which was read by the former. The 1,000-hour tests showed that low plate current was the chief cause of failure in high-voltage tubes and this same cause together with cathode defects were troublesome in miniature tubes. Other types of failures were intermittent short circuits, heater defects, faulty cutoff, grid emission, and mechanical defects. Life-expectancy and survival curves developed from test data were found to be more or less conclusive.

"Performance of Electron Tubes in the ENIAC," by W. E. Erion and H. W. Spence, Aberdeen Proving Ground, and presented by Mr. Erion, was the last paper of the session. This paper covered the findings of a 9-month test on tubes used in ENIAC, those tubes which are normally off and normally on. It was found that by giving an 8-hour "overhaul" at the beginning of each week to the computer, there are comparatively few tube failures in the remaining 112 hours of weekly operation. Checking of 10 types of tubes showed that they had a useful life from 6,000 to 12,000 hours, and the authors gave the reasons for the different tubes' failures; short-circuited elements, open filaments, and low emission were the principle causes of failure.

The afternoon session was devoted to electron tube problems and S. N. Alexander of the National Bureau of Standards presided over the meeting. J. O. McNally, Bell Telephone Laboratories, opened the session with "Design and Operation of Tubes for Long Life," in which were given the results of tests on 1,000 tubes on their cathode temperature for different heater voltages. One of the conclusions reached was that tubes should be run with slightly less than their rated voltages on the elements in order to give longer life. From a test of approximately 1,600 tubes, it was shown that there was no great advantage in removing tubes after a certain number of hours of active life; the percentage of tubes surviving plotted against time follows rather closely an exponential curve.

The next speaker, J. R. Steen, Sylvania Electric Products, Inc., discussed "The JETEC Approach to the Tube Reliability Problem." The Joint Electron Tube Engineering Council (JETEC) investigates various engineering problems and gives its findings to the parent association of which the National Electrical Manufacturers Association and the Radio Television Manufacturers Association are members. Mr. Steen defined reliability of tubes, which covers many different phases of use. The JETEC ratings take into consideration the application to which a tube is put. It was brought out that in order to obtain greater reliability in tubes, there should be closer co-operation between the tube manufacturer and the users—that more information should be exchanged.

1951 Summer General Meeting Committee

The General Committee for the 1951 AIEE Summer General Meeting is shown preparing plans for this important meeting to be held at the Royal York Hotel, Toronto, Ontario, Canada, June 25 to 29, 1951. Committee chairman, O. W. Titus, estimates that about 1,800 will be registered for this meeting. Above, left to right, seated: J. T. Fisher, Bell Telephone Company of Canada, 76 Adelaide Street, West, Toronto, Secretary; W. R. Harmer, Hydro-Electric Power Commission (HEPC) of Ontario, Vice-Chairman; O. W. Titus, Canada Wire and Cable Company, Chairman; A. H. Frampton, English Electric Company of Canada, Ltd., Vice-President District 10; D. F. Martin, Packard Electric Company, Ltd.; J. H. Smith, Canadian General Electric Company. Standing, left to right: M. C. Thurling, Canadian General Electric Company, Treasurer; G. A. Brace, Ferranti Electric Ltd.; M. J. McHenry, HEPC of Ontario; J. T. Thwaites, Canadian Westinghouse Company; J. Y. Doran, Toronto Transportation Commission (representing, at the time of the picture, committee member J. G. Inglis); Marino Fraresso, HEPC of Ontario; D. G. Geiger, Bell Telephone Company of Canada (member-at-large); E. M. Haacke, Electrical News and Engineering; P. J. Croft, Canada Wire and Cable Company. Missing from the photograph is W. J. Gilson, a member-at-large

Future AIEE Meetings

Southern District Meeting (*page 165*)
Macfadden-Deauville Hotel, Miami Beach, Fla.
April 11–13, 1951
(*Final date for submitting papers—closed*)

North Eastern District Meeting
Hotel Syracuse, Syracuse, N. Y.
May 2–4, 1951
(*Final date for submitting papers—February 1*)

Great Lakes District Meeting
Loraine Hotel, Madison, Wis.
May 17–19, 1951
(*Final date for submitting papers—February 16*)

Summer General Meeting (*page 163*)
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(*Final date for submitting papers—March 27*)

Pacific General Meeing
Multnomah Hotel, Portland, Oreg.
August 20–23, 1951
(*Final date for submitting papers—May 21*)

Fall General Meeting
Hotel Cleveland, Cleveland, Ohio
October 22–26, 1951
(*Final date for submitting papers—June 22*)

"Cathode Interface Impedance and Its Effects in Aged Vacuum Tubes" was the subject of H. B. Frost, Massachusetts Institute of Technology. The oxide coating on the nickel core of the cathode has an interface which is equivalent to a parallel resistance-capacitance circuit, which acts like a semiconductor and it is unwanted for a long tube life. An accelerated life test has been devised and results seem to indicate that the interface depends on the metal of which the cathode is made, that is, the nickel and the amount of silicon in it.

L. S. Nergaard, Radio Corporation of America Laboratories, carried the discussion of the cathode interface further in his paper, "Cathode Impedance and Tube Failure." He brought out that the rate of growth of the interface is an important factor as well as the duty cycle; the lower the duty, the higher the growth of interface resistance.

The last paper of the afternoon, "6SN7WGT and 6AN5; Mutual Conductance Dispersion and the Effect of Low Duty Cycle Operation on Long Life Performance" was given by I. Levy, Raytheon Manufacturing Company. The two tubes mentioned in the title of the paper are "ruggedized" and, in the course of tests for computer use, were subjected to shock tests. It was found that the transconductance dispersion was an important factor; the longer the life, the greater this dispersion, but a lot of 25 tubes showed that the majority of them would be acceptable. The author also discussed the make-up of the cathode interface layer and its influence on tube performance. He explained about normal and passive alloy cathodes and it was thought that the latter was preferable.

An open discussion on "Improved Electron Tubes for Computers" was the final event of the session in which the following subjects were considered: the possibilities of an accelerated life test; the use of a shock-testing machine and its effect on an accelerated test; noises in tubes; and a reciprocal educational exchange between computer circuit designers and tube manufacturers.

A. L. Samuel, International Business Machines Corporation, was the chairman of the evening session on special purpose computer tubes. The first paper, "A Stable Binary Electrostatic Storage System," was given by A. M. Clogston, Bell Telephone Laboratories, who explained the functioning of the storage tube. The next speaker, J. Rajchman, Radio Corporation of America, described how another type of tube functioned in his paper, "Recent Experiences with the Selective Electrostatic Memory Tube," and how the tube operated and its improvements. "The MIT Storage Tube" was the subject of P. Youtz, Massachusetts Institute of Technology. This beam-deflection storage tube, which was described in *Electrical Engineering*, November 1950, page 990, was tested in a pilot tester and run 8 hours daily for a month. The speaker described the tests and the theory underlying the tube, stating that even as yet some phases of its operation are not clearly understood; for example, some of the spot interaction.

T. Van Dyk, Rogers Majestic Electronics, Ltd., of Canada, described "The Development of the Rogers Additron," which is an electrostatically focussed radial double-beam tube primarily for use as a binary adder tube in high-speed digital computers. The internal construction of the tube consists of 12 control elements placed symmetrically and circularly around the cathode and connected to form three electrodes. Twelve collector elements are placed on a circle and opposite the gaps between the control elements. Alternate collector elements are connected internally to form two collector electrodes and these are shielded from each other by a screen. If one of the eight possible combinations of a zero voltage and a positive voltage is applied to the three control electrodes, the electrostatic field set up in conjunction with the self-bias of the tube directs the electron beams to either a sum or a carry collector element, to neither, or to both.

"A Proposal for a Binary Adder Tube Utilizing Beam Deflection Principles" was presented by D. H. Gridley, Naval Research Laboratory. In this tube the circular beam is replaced with one of a "ribbon" cross section formed by an electron lens. This may be a double-beam tube with six anodes or targets, two sets of deflection plates, and four inputs, but these can be used in single form.

The last three papers of the session dealt with counting tubes, the first of these being "Special Cold Cathode Discharge Tube for Counting and Switching Applications" by M. W. Wallace and J. Heney, Federal Telecommunications Laboratories, and presented by the former; the second paper, "A Decimal Counting Tube," was given by T. R. Kohler, Phillips Laboratories; and the final one by F. J. Cooke, Remington Rand Corporation, was on "New Improvements and Applications in Remtron Counter Tubes." The first of these papers described several types of gas-filled tubes, which in general are slower than vacuum tubes. Mr. Kohler described a Dutch decade counter in which a ribbon-shaped beam is focussed on a slotted screen in which are openings of different widths, this electron beam being used as a counter. The Remtron tube, described in the last paper of the session, is described as being economical and will function at 100 kc.

The morning session of December 12 was devoted to tube manufacture and crystal diode experience and J. G. Brainerd, University of Pennsylvania, was the chairman. The first paper, "Design and Manufacture of Electron Tubes for Electronic Computer Service," was presented by R. E. Higgs and H. E. Stuman, Radio Corporation of America, and read by the former. The design requirements of computer tubes were discussed and by using the plate-current equation it was shown how the plate current depends directly on the cathode area and inversely as the square of the grid-to-cathode spacing. The on-off service of tubes causes a relatively short life due to the cathode interface and the silicon in the cathode sleeve that causes the trouble. Another troublesome factor is any mobility of the control grid, which should be sprayed with lampblack to prevent secondary emission, as the grid is often driven positive. Various other factors in tube manufacture were discussed: experienced operators for assembly; careful control of parts; removal of all foreign matter from interior of tubes.

The second paper, "Problems in the Manufacture of Special Tubes for Computer Use," was by R. L. McCormack, Raytheon Manufacturing Company, and read by Mr. Rockwood. After discussing reasons for tube failure—either poor manufacture or poor use on the part of the circuit designer—he told about manufacturing objects and how quality is influenced by processing and testing. Methods of life tests were explained: 80 per cent of tubes tested must pass, so that four out of five tubes will work satisfactorily.

R. W. Slinkman, Sylvania Electric Products, Inc., presented "Development of the 7AK7." This gate tube was developed two years ago especially for binary computers with a fast pulse rate and was put into production in four months, about one-half the usual allowable time. The economical aspects of putting a new tube into production were outlined and a comparison made between tubes for television receivers and those for computers.

"Application of Germanium Diodes in Computers" was given by N. DeWolff, General Electric Company, in which he described the manufacturing difficulties encountered and the tests made. Oscillograms were shown illustrating good and bad up-drift, down-drift back currents.

"SEAC Experience with Germanium Diodes," written by J. H. Wright and R. J. Slutz, both of the National Bureau of Standards, was presented by Mr. Wright. A description was given on how the switching in SEAC was performed by the 16,000 germanium diodes and how they are used in flip-flop circuits. In approximately 2,500 hours of use there was 0.4 per cent failure during computer breakdown.

H. B. Frost, Massachusetts Institute of Technology, presented his second paper of the conference, "Crystal Diode Life Experience in the Whirlwind Computer Circuits." He told about the 9,500 diodes in the Whirlwind computer and how it was found that diodes used in flip-flop circuits have about one-half the life of those employed in other circuits.

J. H. Bigelow of the Institute for Advanced Study presided over the final session of the conference devoted to the Williams type storage. H. D. Huskey of the National Bureau of Standards opened the session with "Tube Experience in the SWAC." In this instrument information is stored on 37 cathode-ray tubes with which the Bureau has had approximately 1,500 hours' experience. This information is stored as 256 spots, which are regenerated once every 4 milliseconds. Double this number of spots have been tried, but here there is a chance that the electron beam might discharge adjacent spots. An average cathode-ray tube has three or four flaws on its screen so that storage cannot be effected without special care.

"SEAC Storage Tube Memory System" by William Davis, National Bureau of Standards, contained a description of the Williams tube technique, which was proposed by Williams in 1947 and the first one built at the University of Manchester, England. SEAC is capable of storing one binary digit unit every 48 microseconds and the tests which it has undergone thus far have been successful.

J. H. Pomerene, Institute for Advanced Study, described the testing of the 40 Williams tubes employed in the Institute's instrument, where 1,024 spots can be put in. Bad flaws are detected in cathode-ray tubes by Lissajous figures generated by two oscillators slightly out of phase.

"Apparatus for Selection of Cathode-ray Tubes for a Williams Storage" by David Friedman, National Bureau of Standards, contained data concerning the tests for blemishes on the tubes' screens; the line-of-dots test and the circuit used; and the electrical spot diameter test. Tubes used in SEAC are tested during use and indications are given as to the location of any blemish and on what tube it occurs.

The last three papers covered the underlying theory of the functioning of the Williams storage tube; these were presented by J. Kates, University of Toronto; A. Holt, National Bureau of Standards; and L. Brillouin, International Business Machines Corporation. The differences of opinions expressed by these authors evoked a most spirited discussion.

500 Expected to Attend Southern District Meeting in Miami Beach

Those who attend the AIEE Southern District Meeting at Miami Beach, Fla., April 11–13, 1951, will find themselves quartered in some of the city's finest and most luxurious hotels in the North Beach section. Meeting headquarters will be at the Macfadden-Deauville Hotel on Collins Avenue. The rear of the hotel faces the Atlantic Ocean with one of the finest sections of bathing beach. The beach is flanked by an array of cabanas, each equipped with private dressing rooms, showers, furniture, and clothes closets. Between the cabanas and the hotel is a swimming pool of Olympic proportions, with 14 feet of water at its deepest point. The pool slopes to shallower water which, at the ends, can accommodate small children.

The adequacy of the beach and swimming pool is typical of the accommodations

Sunswept pool and cabanas of the Macfadden-Deauville Hotel are only a small part of the many attractions at AIEE Southern District Meeting headquarters

awaiting the members of the Institute. The Macfadden-Deauville Hotel is too small to house the 500 persons expected to attend, so nearby hotels will also be used. The students, for example, will stay at the Northshore Hotel. This is a beautiful hotel with its own pool and dock facilities. It is near the headquarters hotel and is located on an island in Biscayne Bay. Other members will stay at the Sherry Frontenac and the Monte Carlo hotels, which lie along the oceanfront immediately south of the Macfadden-Deauville.

In the North Beach section are numerous attractive hotels, homes, and apartment buildings. There are two distinct shopping areas, each boasting a wide variety of stores. A bank, beauty salons, a wide selection of eating places, public oceanfront bathing beaches, and a movie house are in the immediate vicinity.

Members attending will do well to bring along their summer clothing. April temperature in Miami Beach averages 73.9 degrees, an ideal temperature for swimming, sunbathing, fishing, boating, golf, tennis, sightseeing, and the many other activities available here.

The members of the Southern District Meeting Committee are: Harvey F. Pierce, *General Chairman;* C. K. Lingo, *Publicity and Attendance;* Ollie T. Ayers, Jr., *Hotels and Registration;* Dr. H. H. Sheldon, *Technical Papers;* J. W. Lacy, Jr., *Program;* E. F. Johnson, *Finance;* J. W. Bevelle, *Transportation and Inspection Trips;* and C. W. Cogburn, *Sports and Entertainment.*

Technical and Student Paper Prize Awards Are Announced

TECHNICAL PAPERS

J. J. Orr, Chairman of the Committee on Award of Institute Prizes, has announced the award of the Institute Paper Prizes in each of the five technical classes for papers presented during the period August 1, 1949, to July 31, 1950. Several of the division nominating committees found it difficult to choose a first and second preference from among the technical papers in their field. However, the final decisions are quite definite. The papers selected for first and second prize are as follows:

Communication Division

First Prize awarded to:
Fundamentals of the Automatic Telephone Message Accounting System, John Meszar, Bell Telephone Laboratories, Inc.

Second Prize awarded to:
A New Electronic Telegraph Regenerative Repeater, B. Ostendorf, Jr., Bell Telephone Laboratories, Inc.

General Applications Division

First Prize awarded to:
Noise Evaluation of Fluorescent Lamp Ballasts, C. P. Hayes, H. R. Gould, General Electric Company

Second Prize awarded to:
Effect of Frequency on Perception Currents, C. F. Dalziel, University of California, and T. H. Mansfield, Tracerlab, Inc.

Industry Division

First Prize awarded to:
A Frequency-Response Method for Analyzing and Synthesizing Contactor Servomechanisms, Ralph J. Kochenburger, University of Connecticut (also Alfred Noble Prize award)

Second Prize awarded to:
Prediction of Ultimate Temperature Rise from Early Heat Run Data, J. E. Ryan, General Electric Company

Power Division

First Prize awarded to:
Coordination of Fuel Cost and Transmission Loss by Use of the Network Analyzer to Determine Plant Loading Schedules, E. E. George, H. W. Page, Ebasco Services, Inc., and J. B. Ward, Purdue University

Second Prize awarded to:
Interrupting Ability of Horn-Gap Switches, F. E. Andrews, L. R. Janes, M. A. Andersson, Public Service Company of Northern Illinois

Science and Electronics Division

First Prize awarded to:
Statistical Nature and Physical Concepts of Thyratron Deionization Time, H. A. Romanowitz, University of Kentucky, and W. G. Dow, University of Michigan

Second Prize awarded to:
The Theory of the Current Transductor and Its Application in the Aluminum Industry, T. R. Specht, Westinghouse Electric Corporation, and R. N. Wagner, Aluminum Company of America

STUDENT PAPERS

The Committee on Award of Institute Prizes has announced the award of the Best Student Paper Prizes for papers presented during the period August 1, 1949, to July 31, 1950. The committee reviewed all of the papers submitted for this prize, three reviews having been secured for each Student paper. Several of the papers considered for the second prize were of such a high order that

the choice was very difficult. However, the final decisions were unanimous in all cases. The papers selected for the awards and honorable mention are as follows:

Best Student Paper Prize

Prize awarded to:
Recording Styli, the Burnishing Facet, and a Process for Resharpening, Charles F. Strandberg, Duke University

Second Prize Student Paper

Prize awarded to:
A Stroboscopic Earth Inductor Compass, Samuel A. Schwartz, University of Alabama

Honorable Mention

Awarded to:
The Reproduction of Electron Tube Characteristic Curves on the Cathode-Ray Oscilloscope, H. S. Ingraham, Jr., University of Maine

AIEE Nominating Committee to Meet in New York City

The Nominating Committee of the AIEE will meet at the Hotel Statler, New York, N. Y., January 24, 1951, during the Winter General Meeting to nominate candidates for AIEE offices to be voted on by the membership in the spring of 1951. Members of the committee are as follows:

Representing the Board of Directors:

W. L. Everitt, University of Illinois, Urbana, Ill.

R. A. Hopkins, Westinghouse Electric Corporation, Los Angeles, Calif.

J. A. McDonald, General Electric Company, Salt Lake City, Utah

Elgin B. Robertson, Elgin B. Robertson, Inc., Dallas, Tex.

Walter J. Seeley, Duke University, Durham, N. C.

Representing the ten geographical Districts:

1. F. S. Bacon, Jr., Rockbestos Products Corporation, New Haven, Conn.

2. J. A. Dinwiddie, Westinghouse Electric Corporation, Toledo, Ohio

3. J. D. Tebo, Bell Telephone Laboratories, Inc., New York, N. Y.

4. J. H. Berry, Virginia Electric and Power Company, Norfolk, Va.

5. J. C. Woods, Commonwealth Edison Company, Chicago, Ill.

6. H. F. Gidlund, Public Service Company of Colorado, Denver, Colo.

7. J. Bruce Wiley, University of Oklahoma, Norman, Okla.

8. T. M. Blakslee, Department of Water and Power, Los Angeles, Calif.

9. Michael D. Duffy, Pacific Power and Light Company, Portland, Oreg.

10. W. R. Harmer, Hydro-Electric Power Commision of Ontario, Toronto, Ontario, Canada

Alternates for Board representatives:

Walter J. Barrett, New Jersey Bell Telephone Company, Newark, N. J.

M. D. Hooven, Public Service Electric and Gas Company, Newark, N. J.

Alternates for District representatives:

1. R. V. Shepherd, General Electric Company, Schenectady, N. Y.

6. J. O. Kammerman, South Dakota School of Mines and Technology, Rapid City, S. Dak.

7. Marian J. Smith, Texas Technological College, Lubbock, Tex.

9. Charles B. Carpenter, Pacific Telephone and Telegraph Company, Portland, Oreg.

AIEE Lehigh Valley Section Holds Meeting at Allentown, Pa.

One hundred and fifty members of the AIEE Lehigh Valley Section attended a dinner meeting at the Masonic Temple, Allentown, Pa., on December 8, and heard Larston D. Farrar, writer and lecturer of Washington, D. C., discuss national politics. Mr. Farrar stressed the need of careful voting for candidates, and he warned the members to pay greater attention to national elections than to local ones. Illustrative of the point, he said, "is the noise made by citizens when local governments make small tax increases, and silence or unawareness on the part of the same people when Congress makes appropriations of billions of dollars." The talk was followed by an interesting question-and-answer period.

Shown at the Lehigh Valley Section meeting are, left to right, Larston D. Farrar, lecturer; Stanley C. Townsend, Allentown (Pa.) District Manager; and D. A. Campbell, Jr., Vice-Chairman of the Lehigh Valley Section

Student Branch of Newark College Meets. The Newark College of Engineering held a student branch meeting on November 14, 1950. This meeting was sponsored by the International Business Machines Corporation, and was held at their Newark office. R. A. Wadsten, technical sales representative, and C. Anderson, customer engineer, presented talks on Electronic Calculation and Calculators.

Over 200 Attend Third Annual AIEE Machine Tool Conference

Electrical engineers in the machine tool industry had the opportunity to hear some excellent technical papers and take interesting inspection trips during the 3-day conference on machine tools. The Third Annual AIEE Special Conference on Machine Tools was held November 14, 15, and 16 at the Sheraton Hotel in Worcester, Mass., and was sponsored by the Machine Tool Subcommittee of the Committee on General Industry Applications, with Don R. Percival as chairman. Total attendance was more than 200.

During the morning session of the first day, four papers were presented. The afternoon was devoted to plant visitations in and around Worcester, Mass. At a dinner that evening, Frank J. Oliver, editor of *Electrical Manufacturing*, was the speaker. Six papers were given on November 15, and there was a meeting of the Subcommittee on Machine Tools. Following the afternoon meeting, approximately 150 conference delegates left for Springfield, Vt., where the final day of the conference was spent visiting four machine tool plants in the Windsor-Springfield area.

Assisting the Machine Tool Subcommittee in making arrangements for the conference were: R. E. Pfeif, *Chairman*, Worcester Section, AIEE; B. F. Hammarstrom, *Chairman*, Committee in Charge of Local Arrangements; G. R. Blake, G. W. Bibber, *Registration;* W. H. Howard, B. F. Hammarstrom, *Publicity;* W. G. Coleman, P. F. Dunigan, *Finance and Dinner;* S. I. Rice, *Plant Visitation.*

Comments Are Requested on Ground-Fault Neutralizers Guide

Improvement in service is a factor in power transmission and distribution which has received considerable emphasis in recent years. One of the means of obtaining improvement in service reliability is the ground-fault neutralizer. It was first applied in this country in 1921. However, the acceptance of neutralizers as a protective device for transmission and distribution systems has come only in recent years. Prior to 1937 only a scattered few neutralizers were installed, and since that time their application has increased year by year.

Coincident with the increased interest in ground-fault neutralizers, a number of papers

R. A. Wadsten and C. Anderson are shown speaking to Newark College of Engineering students at a student branch meeting

have been presented and articles have appeared in the trade journals treating the various aspects of neutralizers—their design, features of certain applications, operating results, and other general information. However, a comprehensive guide for application has not appeared in the literature.

Neutralizers have been installed on overhead line and underground cable systems in this country with voltages from 2.4 kv to 230 kv. Their choice for application as a protective device depends on an analysis weighing the benefits of the various protective schemes, and the comparative economics.

Recognizing this fact, an application guide was prepared to present the various criteria which may effect a proper application of a ground-fault neutralizer to a system. To accomplish this purpose, the guide is divided into four sections: the ground-fault neutralizer; ratings of ground-fault neutralizers; application criteria; installation and operation criteria.

Ground-fault neutralizers can be installed on any 3-phase transmission system, whether radial or network, provided certain application criteria are met. In the four sections of the guide, these criteria are presented and discussed.

The Guide for Application of Ground-Fault Neutralizers (Miscellaneous Paper 49-283) was presented at the Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949, on a 1-year trial basis with the thought that it would be revised and put in final form at the end of the trial period. A few copies are still available from the AIEE Order Department. The working group which prepared this guide is anxious to receive comments and suggestions so that the guide will represent current practice. These comments should be sent to the chairman of the working group, Mr. J. E. Clem, General Electric Company, 1 River Road, Schenectady 5, N. Y., as early as possible.

Members' Views Asked on Neutral Grounding Application Guide

The proper way to ground the neutral or neutrals of a 3-phase electric system has been a much debated subject from the beginning of the electrical industry. Resistance, reactance, direct-grounded, and isolated neutrals have all been tried, and it has been demonstrated repeatedly in practice that workable systems are available with any of the various methods that might be used. Accordingly, it should be recognized that there is no one universal answer to the neutral grounding problem. However, it is possible to establish certain criteria that are desirable in the grounded systems and once the desired objectives are decided it is relatively simple to select the method of grounding that best fulfills the requirements.

The purpose of this grounding guide is to give some of the basic factors to be considered in selecting any particular type of transmission system neutral grounding, the types of apparatus that may be used, and the methods to be employed. It is limited to systems 23 kv and above without directly connected generators.

The Application Guide on Methods of Neutral Grounding on Transmission Systems was presented at the Fall General Meeting in Cincinnati, Ohio, October 17–21, 1949, on a 1-year trial basis with the thought that it would be revised and put in final form at the end of the trial period. It was made available on an Advance-Copy-Only basis and copies are no longer available, but the AIEE Protective Devices Committee is anxious to receive comments and suggestions from those who have copies so that the guide will represent current practice. These comments should be sent to the chairman of the working group, Mr. E. M. Hunter, General Electric Company, 1 River Road, Schenectady 5, N. Y., as early as possible.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Industry Division

Committee on Electric Welding. (*Myron Zucker, Chairman; Robert C. McMaster, Vice-Chairman; C. B. Clark, Secretary.*) Due to the success of the two former Special Technical Conferences sponsored by this committee in co-operation with the American Welding Society, it has been decided to organize another one to be held in Detroit, Mich., in April 1952. It has been suggested also that the Power Supply Subcommittee arrange a session at the 1951 Summer General Meeting in Toronto and that papers be presented by members of the Manufacturer, User, and Utility Groups.

The initial phases of the activities planned by the Fundamental Electric Arc Research Subcommittee (R. C. McMaster, Chairman) will include: (1) preparation of a bibliography on past fundamental research; (2) continuous interchange of information on research now in progress; and (3) promotion of interest and activity in fundamental arc research.

Committee on General Industry Applications. (*Kennard Pinder, Chairman; J. C. Find, Vice-Chairman; V. O. Johnson, Secretary.*) The subcommittees of this committee have devoted a large part of their time to the organization of Special Technical Conferences. Due to the broad field of electrical engineering it has become necessary for engineers to specialize in different phases of the subject. The experience of this committee has shown quite clearly that in order to bring the Institute and these specialized engineers together it is important to group them and tie them together by common interest. This results in mutual benefit to the Institute, its local Sections, and engineers attending the Conferences. An individual engineer often finds it difficult to attend a General Meeting in order to listen to one or two papers dealing with his interest. On the other hand he finds more encouragement from his management to attend a one-to-three-day Conference devoted exclusively to the electrical problems in his specific industry. All of the Special Technical Conferences to date have been arranged by a technical committee or subcommittee jointly with a local AIEE Section.

The Rubber and Plastics Industries Subcommittee is planning a fourth annual Technical Conference to be held in Atlantic City in April 1951. The Textile Industry Subcommittee is planning a Technical Conference at the Georgia Institute of Technology, Atlanta, Ga., next spring.

Committee on Mining and Metal Industry. (*T. B. Montgomery, Chairman; A. C. Muir, Vice-Chairman; L. N. Grier, Secretary.*) At a meeting of this committee held in Cleveland, Ohio, September 26, it was suggested that a new subcommittee be appointed to be called Subcommittee on Hard Rock Mining, with Mr. A. B. Chafetz named as Chairman.

The committee is planning a symposium for the Summer General Meeting to be held in Toronto. It has been suggested that this might be built around the subject of Labrador ore mining. A recommendation was also made that the committee sponsor a steel session at the Fall General Meeting in Cleveland, Ohio. The Subcommittee on Mining plans to undertake work on the revision of the American Standard for Installing and Using Electrical Equipment in Metal Mines.

Power Division

Committee on Switchgear. (*H. V. Nye, Chairman; R. L. Webb, Vice-Chairman; J. M. Geiger, Secretary.*) The Working Group on Automatic Circuit Reclosures is now working on a revision of Proposed Standard *50*, which was issued a year ago with the intention that it could be made a full-fledged AIEE Standard by next year. The Working Group on Low-Voltage Air Circuit Breakers is preparing a test code for these circuit breakers. A guide for their application is now available. The Subcommittee on Switches, Fuses, and Insulators has been requested to revise Standard *224* to include "Maximum Design Voltage." This proposed Standard for Air Switches, Insulator Units, and Bus Supports has been out on trial use for a year.

Science and Electronics Division

Committee on Computing Devices. (*J. G. Brainerd, Chairman; W. H. MacWilliams, Jr., Vice-Chairman; and F. J. Maginniss, Secretary.*) A questionnaire has recently been sent out by Dr. MacWilliams, Jr., to a number of people interested in computing equipment preparatory to making up a bibliography of published computer literature. The proposed bibliography will be prepared jointly with the Electronic Computers Committee of the Institute of Radio Engineers (IRE). Although it is too early to set a publication date, the committee is aiming for spring or summer of this year.

In December this committee was a joint sponsor of the Conference on Electron Tubes for Computers sponsored jointly by the AIEE and IRE in collaboration with the Panel on Electron Tubes of The Research and Development Board. Dr. J. G. Brainerd and Dr. S. N. Alexander, Chairman of Sub-

committee on Digital Computers, each presided over one of the sessions at this conference. Two sessions at the Winter General Meeting in New York were devoted to computing devices papers, and plans are now under way for a session at the North Eastern District Meeting.

Electron Tubes Subcommittee of Committee on Electronics. (*H. C. Steiner, Chairman.*) One of the activities of this subcommittee during the past year was the sponsoring jointly with the Institute of Radio Engineers of a Conference on Electronic Devices. This Conference was held at the University of Michigan, Ann Arbor, Mich., on June 22 and 23, 1950, and was conducted on an informal basis, with no published papers and no minutes of the meetings, but every effort was made to encourage discussion of the latest theories and discoveries. The meeting at Ann Arbor was devoted primarily to a discussion of microwave tubes and techniques, and reports from those attending indicate that it was very successful and the exchange of ideas beneficial.

The 1951 Joint Conference will be held at the University of New Hampshire on June 21 and 22.

AIEE PERSONALITIES.....

O. B. Blackwell (A '08, M '13, F '17, Member for Life), has been awarded the 1950 Edison Medal "for his pioneer contributions to the art of telephone transmission." Mr. Blackwell, who is Assistant Vice-President (retired) of the American Telephone and Telegraph Company (AT&T), received the medal at the AIEE Winter General Meeting. He was born on August 21, 1884, in Bourne, Mass., and in 1906 he graduated from Massachusetts Institute of Technology with a bachelor of science degree in electrical engineering. That same year he began his career with the Bell System in the transmission and protection division of the AT&T Engineering Department, and in 1914 he was placed in charge of that department. When the Department of Development and Research was organized in 1919, he became transmission development engineer. In 1934, when this department was consolidated with the Bell Laboratories, Mr. Blackwell was appointed director of Transmission Development. The following year he was named manager of Staff Departments and in 1937 he became a Vice-President. Mr. Blackwell returned to AT&T in 1944 as Assistant Vice-President and also became a member of the Bell Telephone Laboratories' Board of Directors. The medalist is holder of 22 patents in the communication field. He is a member of

O. B. Blackwell

the Acoustical Society, the American Physical Society, the American Society for the Advancement of Science, and the Institute of Radio Engineers. Mr. Blackwell has actively served the AIEE on the following committees: Telegraphy and Telephony; Meetings and Papers; Executive; Standards; Communication; Finance; Headquarters; Lamme Medal.

Vannevar Bush (A' 15, M '19, F '24, Honorary Member), President, Carnegie Institution of Washington, Washington, D. C., has been awarded the John Fritz Medal for "outstanding scientific contributions to his country and to his fellow men." The medal was presented to Doctor Bush at the AIEE Winter General Meeting. He was born at Everett, Mass., on March 11, 1890. He received the bachelor and master of science degrees in 1913 from Tufts College, Boston, Mass., where he became an instructor in mathematics after graduation. He was advanced to assistant professor of electrical engineering in 1916, and in the same year received doctor of engineering degrees from Massachusetts Institute of Technology (MIT) and Harvard University. Research on submarine de-

Vannevar Bush

tection with a special board on submarine devices of the United States Navy occupied him from 1917 to 1918. In 1919 Doctor Bush began a 20-year association with MIT, Cambridge, Mass., as associate professor of electric power transmission. He was named Professor in 1923 and Vice-President and Dean of Engineering nine years later. In 1939 Doctor Bush became President of the Carnegie Institution of Washington. Extremely active in the government during World War II, he was a member of the National Advisory Committee for Aeronautics and was its chairman from 1939 to 1941. In addition, he was Chairman of the National Defense Research Committee, 1940–41, and was Director of the Office of Scientific Research and Development in 1941. Doctor Bush is known internationally for his development of mathematical analyzing instruments for solving complex equations in science and engineering, and is the author of many technical books and papers. His accomplishments have been recognized by more than 17 educational institutions who have granted him honorary degrees, and he is the recipient of 13 medals from engineering and other organizations, some of which include: AIEE Lamme (1935) and Edison (1943) Medals; the United States Distinguished Service Medal, 1945; the Washington Award, 1946; and the Hoover Medal, 1947. Doctor Bush is a member of the American Association for the Advancement of Science, the American Physical Society, the National Academy of Sciences, Tau Beta Pi, Sigma Xi, and Phi Beta Kappa. Doctor Bush was a Director of the AIEE from 1937–41 and has served actively on many Institute committees, some of these being: Electrophysics; Power Transmission and Distribution; Education; Co-ordination of Institute Activities; and Research.

K. T. Compton (F '31), Chairman of the Corporation of Massachusetts Institute of Technology (MIT), has been awarded the Hoover Medal for 1950 for "distinguished public service." The award was presented

K. T. Compton

to Doctor Compton at the AIEE Winter General Meeting. He was born September 14, 1887, in Wooster, Ohio, and received the degrees of bachelor of philosophy, 1908, and master of science, 1909, from Wooster College and the degree of doctor of philosophy from Princeton University in 1912. He was a member of the Wooster College, Wooster, Ohio, and Reed College, Portland, Oreg., faculties before becoming assistant professor of physics at Princeton University, Princeton, N. J., in 1915. Doctor Compton was Chairman of the Department of Physics at Princeton University when, in 1930, he was appointed President of MIT. He was named Chairman of the MIT Corporation in 1948. Doctor Compton is a holder of the Washington Award for 1947, and the American Academy of Arts and Sciences' Rumford Medal. He has been honored many times with the honorary degrees of doctor of science, doctor of laws, and doctor

of engineering. He is a member of the American Optical Society, American Physical Society, Franklin Institute, American Academy of Arts and Sciences, and the author of some 100 publications dealing with electrical and physcial research and developments. Doctor Compton served on the AIEE Edison Medal Committee from 1940–45.

R. J. Kochenburger (A '49), assistant professor of electrical engineering, University of Connecticut, Storrs, Conn., has been awarded the Alfred Noble Prize for 1950 for his paper "A Frequency-Response Method for Analyzing and Synthesizing Contactor Servomechanisms." The prize was presented to him at the AIEE Winter General Meeting. Doctor Kochenburger was born on November 2, 1919, in Jersey City, N. J. He was graduated from Massachusetts Institute of Technology in 1940 with the degree of bachelor of science in electrical engineering and received his master of science degree from the same

R. J. Kochenburger

institution in 1941. He was with the Curtiss Propeller Division of the Curtiss Wright Corporation in Caldwell, N. J., as research engineer from 1941 to 1946, and in 1946 returned to MIT to obtain his doctor of science degree in electrical engineering. Doctor Kochenburger joined the faculty of the University of Connecticut as assistant professor in 1950. He is a member of Sigma Xi and Eta Kappa Nu.

E. C. Crittenden (A '19, M '22, F '44), associate director of the National Bureau of Standards, Washington, D. C., has retired. He was born on December 19, 1880, in Oswayo, Pa. After graduating from Cornell University, Ithaca, N. Y., he remained as an instructor in physics for four years. In 1909 he began his career with the National Bureau of Standards as an assistant physicist in the Photometric Laboratory. In 1921 Doctor Crittenden became chief of the electrical division and remained in this position until 1933, when he was made assistant director. In this latter position he was responsible for the over-all research activities of the Bureau, in addition to his duties as a member of many Bureau committees. Doctor Crittenden is noted for his achievements in the measurement and standardization of light. In 1946, he was awarded an honorary doctor of science degree by the Case Institute of Technology, and the Gold Medal of the Illuminating Engineering Society. Doctor Crittenden is also a member of the American Optical Society, the Illuminating Engineering Society, the American Physical Society, American Association for the Advancement of Science, Phi Beta Kappa, and Sigma Xi. Doctor Crittenden has been an active member of the AIEE and has served on the following Institute committees: Lighting and Illumination; Production and Application of Light; Research; Technical Program; Award of Institute Prizes; and Standards.

A. M. Harrison (M '46), manager, medium machine section, D-C Generator Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed manager of the D-C Generator Engineering Department. In his new position, Mr. Harrison will be responsible for the engineering design and development of all medium- and large-sized d-c generator and motors for the company. After graduating from the Carnegie Institute of Technology in 1926, with the degree of bachelor of science in electrical engineering, Mr. Harrison became associated with Westinghouse. He has had several patents granted to him in the field of d-c machine design and has had published several papers and technical articles.

R. A. Galbraith (A '38), Head of Electrical Engineering Department, Syracuse University, Syracuse, N. Y., has been made Dean of the L. C. Smith College of Applied Science at Syracuse University. Doctor Galbraith graduated from the University of Missouri, Columbia, Mo., in 1933 with a bachelor of science degree in electrical engineering and remained as a member of the faculty for two years. He received the doctor of philosophy degree from Yale University in 1937 when he was National Graduate Fellow of Tau Beta Pi. Before going to Syracuse University, Doctor Galbraith was on the faculty at the Georgia Institute of Technology, Atlanta, Ga., and previous to that he was on the staff of the Radar School at the Massachusetts Institute of Technology, Cambridge, Mass. He is currently serving the Institute on the Student Branch Committee.

C. L. Frederick ('46), Owner and Manager, Carl L. Frederick and Associates, Chevy Chase, Md., has been awarded the degree of Doctor of Science by Nebraska Wesleyan University. Mr. Frederick was graduated from Nebraska Wesleyan University in 1925 with a Bachelor of Arts degree in physics and mathematics. In 1927 he received the Master of Arts degree in physics from George Washington University. Mr. Frederick's professional experience is broad in scope. Before entering business for himself he was contractor to the United States Air Force on evaluation of electronic test equipment. He also has been consultant to the Research and Development Board and to the Weapons Systems Evaluation Group, both under the Office of the Secretary of Defense. Mr. Frederick is a member of the American Physical Society, Institute of Radio Engineers, Institute of Aeronautical Engineers, American Chemical Society, and Sigma Pi Sigma.

E. H. Schulz (A '37, M '43, F '50), Chairman, Electrical Engineering Department, Armour Research Foundation, Chicago, Ill., has been named acting chairman of physics research. Dr. Schulz received his Bachelor of Science degree in 1935 and his Master of Science degree in 1936, both in electrical engineering, from the University of Texas. He was awarded his Doctor's degree in 1947 from the Illinois Institute of Technology, Chicago, Ill., while engaged as an instructor in electrical engineering. He became Chairman of the Electrical Engineering Department in 1947, a post he will retain in addition to his new duties. Dr. Schulz is a member of the Institute of Radio Engineers and the American Society for Engineering Education.

E. E. Grazda (A '42), assistant editor, *Electrical Equipment*, Sutton Publishing Company, New York, N. Y., has been named editor of the publication. Mr. Grazda was former associate editor of *Electrical Engineering*. He was graduated from New York University in 1942 with a Bachelor of Science degree in electrical engineering. He became assistant editor of *Electronics*, New York, N. Y., from 1941–42, and in 1943 he joined the Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., as a field engineer. Mr. Grazda has served from 1948–50 on the joint AIEE-IRE Conferences on Electronic Instrumentation in Nucleonics and Medicine. He is a member of the Institute of Radio Engineers and Eta Kappa Nu.

C. W. Higbee (M '37), manager, Electrical Wire and Cable Department, United States Rubber Company, New York, N. Y., has been elected President of the National Electrical Manufacturers Association. Mr. Higbee attended Rensselaer Polytechnic Institute, and after serving in the Engineer Corps as a First Lieutenant during World War I he entered the employ of the United States Rubber Company in 1919. He has been associated with that company continuously, holding the positions of technical superintendent, general sales manager, and manager, his present post.

A. H. Lauder (A '24, M '43, F '49), assistant manager, Large Motor and Generator Divisions, General Electric Company, Schenectady, N. Y., has been appointed manager of engineering for the divisions. Mr. Lauder was graduated from the University of Wyoming in 1922 and came to General Electric that year as a student engineer in the company's Test Course. He joined the Large Motor and Generators Divisions in 1923 and remained until 1945, when he was appointed to the staff of the manager of General Electric's Schenectady Works. He rejoined the Large Motor and Generator Divisions in 1947, and was named assistant manager a year later.

A. L. Davis (M '46), Engineer, Service Engineering Division, General Electric Company, Schenectady, N. Y., has been appointed manager of service of the Transportation Divisions of General Electric's Apparatus Department. The position will be one of

evaluating and analyzing service requirements for the transportation industry. Mr. Davis' previous experience includes association with the Los Angeles (Calif.) Street Railway Company where he was superintendent of car maintenance.

E. E. Cobb (A '31, M '48), Electrical Project Engineer, Ebasco Services, Inc., New York, N. Y., has joined the staff of Westcott and Mapes, Consulting Engineers of New Haven, Conn., as Senior Electrical Engineer. Mr. Cobb received his Bachelor of Science degree in 1929 from Oklahoma Agricultural and Mechanical College.

OBITUARY

Walter Gordon Clark (A '03, F '24, Member for Life), Consulting Engineer, Clark and Son, Inc., Los Angeles, Calif., died December 17, 1950. Mr. Clark was born in Salt Lake City, Utah, on October 23, 1876, and attended the Van Dernalen School of Engineering and the University of California. In 1897 Mr. Clark became superintendent of the Western Electric Light and Power Company of San Francisco, Calif., and in 1900 he helped organize the Kilbourne-Clark Company in Seattle, Wash. Four years later he became engineer and manager of the Ansonia Brass and Copper Company, Ansonia, Conn. From that time on he served in the capacity of consulting engineer. Mr. Clark directed mining developments and hydraulic power installations in the Yukon territory. He also served as consulting engineer in India and as chairman of the board of engineers of the Victoria Falls and Transvaal Power Company in South Africa. Mr. Clark was also a member of the American Society of Civil Engineers, the American Association for the Advancement of Science, and the American Institute of Mining and Metallurgical Engineers.

Frank Thurman Leilich (A '09, M '25), Consulting Engineer, Baltimore, Md., died November 19, 1950. Mr. Leilich was born on July 13, 1888, in Baltimore, Md., and received the degree of electrical engineer in 1908 from the Baltimore Polytechnic Institute. In 1909 he was granted the master of science degree from Lehigh University and the next year became an instructor in electrical engineering at the University of Pittsburgh (Pa.). Mr. Leilich served in the United States Engineer Corps during the first World War. In 1919 he became associated with Consolidated Gas Electric Light and Power Company of Baltimore, Md. In 1941 Mr. Leilich re-entered the military service and served as a Colonel in the United States Army until 1948 when he was honorably discharged. Mr. Leilich served the Institute on the following committees: Power Generation 1926–30, General Power Applications 1935–38.

Birney Clark Batcheller (M '17, Member for Life), retired, died November 27, 1950. He was born in 1865 and was graduated from the Massachusetts Institute of Technology in 1886 with a bachelor of science degree in mechanical engineering. Mr. Batcheller was noted for his work in the pneumatic postal tube system. He designed and directed the construction of the underground pneumatic postal tube systems in Boston, New York, Philadelphia, Chicago, and St. Louis.

Carl Adien Wolfrom (A '10, Member for Life), Palos Verdes Estates, Calif., died on August 3, 1950. Mr. Wolfrom was born on December 22, 1881, in Bellevue, Ohio, and attended the University of Michigan. In 1902 he entered the service of the Utah Power and Light Company.

MEMBERSHIP

Recommended for Transfer

The board of examiners at its meeting of December 21, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Fellow

Adams, F. C., prof. of elec. engg., Worcester Polytechnic Institute, Worcester, Mass.
Bullard, W. R., elec. engr., Ebasco Services, Inc., New York, N. Y.
Calabrese, G., prof. of elec. engg., New York University, New York, N. Y.
Corfield, M. J., elec. engr., Kennecott Copper Corp., Garfield, Utah
Corwith, H. P., vice pres., Western Union Telegraph Co., New York, N. Y.
Crosby, M. G., pres., Crosby Laboratories, Inc., Mineola, N. Y.
Deardorff, H. E., vice pres., The Dayton Power & Light Co., Dayton, Ohio
Dellis, P. L., member of management, SOFINA, Brussels, Belgium
Gardner, M. F., prof. of elec. engg., Massachusetts Institute of Technology, Cambridge, Mass.
Hartley, R. V. L., retired, 174 Summit Ave., Summit, N. J.
Huntley, H. R., telephone engr., American Tel. & Tel. Co., New York, N. Y.
Killingsworth, H. T., vice pres., American Tel. & Tel. Co., New York, N. Y.
Lytle, C. M., mgr. of engineering, Kansas City Power & Light Co., Kansas City, Mo.
McDavitt, M. B., director of switching dev., Bell Telephone Labs., Inc., New York, N. Y.
Parker, J. C., supervisor, insulation test dept., Memphis Light, Gas & Water Div., Memphis, Tenn.
Paxson, H. R., senior engr., Philadelphia Electric Co., Philadelphia, Pa.
Pease, E. I., special asst., Corps of Engineers, Seattle, Wash.
Pierce, H. J., chief engr., Northwestern Bell Tel. Co., Minneapolis, Minn.
Plumb, H. H., head, elec. div., U. S. Bureau of Reclamation, Denver, Colo.
Ransom, G. B., plant extension engr., American Tel. & Tel. Co., New York, N. Y.
Rudge, W. J., div. engr., General Electric Co., Pittsfield, Mass.
Schelkunoff, S. A., member, technical staff, Bell Tel. Labs., Murray Hill, N. J.
Tebo, J. D., science editor, Bell Tel. Labs., New York, N. Y.
Winfield, F. C., partner, Merz & McLellan, Newcastle-upon-Tyne, England

24 to grade of Fellow

To Grade of Member

Ayers, D. P., senior elec. engr., Sverdrup & Parcel, Inc., St. Louis, Mo.
Broadley, W. A., chief elec. engr., National Pneumatic Co., Boston, Mass.
Colby, H. B., system maintenance engr., Public Service Co. of Colorado, Denver, Colo.
Dempsey, J. J., Jr., distribution engr., Puget Sound Power & Light Co., Puyallup, Wash.
Doolittle, O. L., senior engr., Pacific Tel. & Tel. Co., San Diego, Calif.
Dover, R. S., sales engr., Frank W. Yarline & Co., Chicago, Ill.
Edie, L. C., engr., International Tel. & Tel. Corp., New York, N. Y.
Elam, J., asst. prof., Oklahoma A & M College, Stillwater, Okla.
Emmons, P. A., Jr., test engr., Carolina Aluminum Co., Badin, N. C.
Fink, F. P., project mgr., Watson-Flagg Engg. Co., Oak Ridge, Tenn.
Gayer, J. H., elec. advisor, Office of High Commissioner for Germany, U. S. Army, Berlin, Germany
Goobich, A., asst. elec. engr., Hetch Hetchy Power Bureau, San Francisco, Calif.
Greenwood, R. L., consulting & application engr., Westinghouse Elec. Corp., Los Angeles, Calif.
Harder, R. N., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Hoehn, A. J., Jr., elec. engr., Armour Research Foundation, Chicago, Ill.
Hovencyer, W. E., elec. engr., navis cyclotron labs., Columbia University, Irvington-on-Hudson, N. Y.
Iffland, J. J., engr., Capehart-Farnsworth Corp., Ft. Wayne, Ind.
Jeffers, L. M., Jr., asst. elec. engr., Public Utilities Comm., San Francisco, Calif.
Kelley, W. E., draftsman, Pennsylvania Railroad, Philadelphia, Pa.
Kelsay, W. D., engr., Texas Power & Light Co., Dallas, Tex.
Lantz, M. J., elec. engr., Bonneville Power Administration, Portland, Ore.
Lohse, A., elec. engr., Union Oil Co. of California, Oleum, Calif.
Meyers, T. E., chief engr., The Wo.'e & Mann Mfg. Co., Baltimore, Md.
Miller, F. E., estimates & records supervisor, Pacific Gas & Electric Co., Salinas, Calif.
Neu, S. S., assoc. prof. of electricity, Milwaukee School of Engineering, Milwaukee, Wis.
O'Leary, D. F., elec. engr., Boston Edison Co., Boston, Mass.
Ordas, A. F., elec. engr., General Electric Co., Ft. Wayne, Ind.
Nuttall, E. D., electronic engr., United Gas Pipe Line Co., Shreveport, La.
Orfanos, C. J. G., elec. engr., Ebasco Services, Inc., New York, N. Y.
Pumphrey, R. E., div. engr., General Electric Co., Fort Wayne, Ind.
Schwartz, H. E., test engr., Consolidated Gas & Electric Co., Baltimore, Md.
Smith, W. H., asst. engr., Toronto Hydro-Electric System, Toronto, Ontario, Canada
Stannard, G. E., asst. prof. of elec. engg., Worcester Polytechnic Institute, Worcester, Mass.
Stiles, A. M., asst. prof. of elec. engg., University of Denver, Denver, Colo.
Vazquez-Praderi, F., chief interconnecting system, U.T.E., Montevideo, Uruguay, So. Amer.
Webb, A. L., project engr., Bureau of Yards & Docks, Washington, D. C.
West, E. S., senior assoc. engr., Department of Education, Baltimore, Md.

37 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before February 25, 1951, or April 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Badura, C. O., Otis Elevator Co., Yonkers, N. Y.
Chapman, V., Logan Hardware & Supply Co., Huntington, W. Va.
Clover, L. E., General Elec. Co., W. Lynn, Mass.
Comstock, R. H., O. Z. Electrical Mfg. Co., Inc., Brooklyn, N. Y.
Dalla Verde, A., Societa' Idroelettrica Piemonte, Torino, Italy
Das, I. N., Damodar Valley Corp. of Bihar, India, c/o The Kuljian Corp., Philadelphia, Pa.
Durkee, P. A., Automatic Control Co., St. Paul, Minn.
Fich, S., Rutgers University, New Brunswick, N. J.
Goodmon, R. H., Virginia Elec. & Power Co., Williamston, N. C.
Gowdy, G. A., Canton Elec. Light & Power Co., Canton, N. Y.
Gyani, G. S., P.W.D. Electricity Branch, Nangal, Punjab, India, c/o Westinghouse International, New York, N. Y.
Holmes, N., The British General Elec. Co. (Canadian) Ltd., Toronto, Ontario, Canada
Jacobson, E. A., Pacific Gas & Elec. Co., Fresno, Calif.
King, L. C., Jackson & Moreland, Consulting Engineers, Boston, Mass.
Kocher, S. E., Pennsylvania Power & Light Co., Allentown, Pa.
Lucas, F. B., University of Miami, Miami, Fla.
Mast, L. R., Electromode Corp., Rochester, N. Y.
McNeill, W. A., Cooke & Ferguson, Ltd., Manchester, England
Moeller, H. M., Jackson & Moreland, Boston, Mass.
Montgomery, B. E., Civil Aeronautics Admin., Washington, D. C.
Paterson, S. G., Rogers Majestic Electronics Ltd., Leaside, Ontario, Canada
Peterson, G. R., British Electricity Authority, London, England
Rankin, V. C., Western Elec. Co., Chicago, Ill.
Reisig, C. F. (re-election), Niagara Mohawk Power Corp., Niagara Falls, N. Y.
Ruehlemann, H. E., Naval Ordnance Lab., White Oak, Md.
Russell, J. A., Jr., Hampton Institute, Hampton, Va.
Shobert, E. I., H. Stackpole Carbon Co., St. Marys, Pa.
Silva, G., CONIEL, Rome, Italy
Swaim, B. C., Biberstein & Bowles, Inc., Charlotte, N. C.
Swarts, M., Greenville Utilities Comm., Greenville, N. C.
Williams, J. V., Jr., I.B.M. Corp., Poughkeepsie, N. Y.
Winther, M. P., (Eaton Mfg. Co.), 739 E. 140th St., Cleveland, Ohio
Yanuzzi, C. A., Pennsylvania Power & Light Co., Allentown, Pa.

33 to grade of Member

Statement of Principles of Professional Conduct of the American Institute of Electrical Engineers

Adopted by the Board of Directors, August 4, 1950

I. Canons of Ethics
Foreword
Professional Life
Relations with the Public
Relations with Clients and Employers
Relations with Engineers
II. Code of Business Practice
Character of Enterprise with Which the Engineer Is Identified
Ownership of Engineering Data and Records
The Engineer's Relations to the Public and to the Engineering Profession
III. Use of Membership Designations and Institute Insignia

I. Canons of Ethics for Engineers

Being the statement developed and promulgated by the Engineers' Council for Professional Development, as a standard for all national engineering society groups.

Foreword

Honesty, justice, and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. The engineer should recognize such a standard, not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers, and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefit of mankind. He should uphold the honor and dignity of his profession and also avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant.

Professional Life

Sec. 1. The engineer will coöperate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools, and the scientific and engineering press.

Sec. 2. He will not advertise his work or merit in a self-laudatory manner, and he will avoid all conduct or practice likely to discredit or do injury to the dignity and honor of his profession.

Relations with the Public

Sec. 3. The engineer will endeavor to extend public knowledge of engineering, and will discourage the spreading of untrue, unfair, and exaggerated statements regarding engineering.

Sec. 4. He will have due regard for the safety of life and health of the public and employees who may be affected by the work for which he is responsible.

Sec. 5. He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission, or other tribunal.

Sec. 6. He will not issue ex parte statements, criticisms, or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on whose behalf he is making the statement.

Sec. 7. He will refrain from expressing publicly an opinion on an engineering subject unless he is informed as to the facts relating thereto.

Relations with Clients and Employers

Sec. 8. The engineer will act in professional matters for each client or employer as a faithful agent or trustee.

Sec. 9. He will act with fairness and justice between his client or employer and the contractor when dealing with contracts.

Sec. 10. He will make his status clear to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus, or any other thing in which he may have a financial interest.

Sec. 11. He will guard against conditions that are dangerous or threatening to life, limb, or property on work for which he is responsible, or if he is not responsible, will promptly call such conditions to the attention of those who are responsible.

Sec. 12. He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is overruled by nontechnical authority in cases where he is responsible for the technical adequacy of engineering work.

Sec. 13. He will engage, or advise his client or employer to engage, and he will coöperate with, other experts and specialists whenever the client's or employer's interests are best served by such service.

Sec. 14. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

Sec. 15. He will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, without the consent of all interested parties.

Sec. 16. He will not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

Sec. 17. He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

Sec. 18. He will promptly disclose to his client or employer any interest in a business which may compete with or affect the business of his client or employer. He will not allow an interest in any business to affect his decision regarding engineering work for which he is employed, or which he may be called upon to perform.

Relations with Engineer

Sec. 19. The engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

Sec. 20. He will take care that credit for engineering work is given to those to whom credit is properly due.

Sec. 21. He will uphold the principle of appropriate and adequate compensation for those engaged in engineering work, including those in subordinate capacities, as being in the public interest and maintaining the standards of the profession.

Sec. 22. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ.

Sec. 23. He will not directly or indirectly injure the professional reputation, prospects, or practice of another engineer. However, if he considers that an engineer is guilty of unethical, illegal, or unfair practice, he will present the information to the proper authority for action.

Sec. 24. He will exercise due restraint in criticizing another engineer's work in public, recognizing the fact that the engineering societies and the engineering press provide the proper forum for technical discussions and criticism.

Sec. 25. He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the other's employment.

Sec. 26. He will not compete with another engineer on the basis of charges for work by underbidding, through reducing his normal fees after having been informed of the charges named by the other.

Sec. 27. He will not use the advantages of a salaried position to compete unfairly with another engineer.

Sec. 28. He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

II. Code of Business Practice

Being those principles contained in the original code of the Insti-

tute not covered by the Canons of the Engineers' Council for Professional Development.

Character of Enterprise with Which the Engineer is Identified

Sec. 1. It is the duty of the engineer to satisfy himself to the best of his ability that the enterprises with which he becomes identified are of legitimate character. If after becoming associated with an enterprise he finds it to be of questionable character, he should sever his connection with it as soon as practicable.

Ownership of Engineering Data and Records

Sec. 2. It is desirable that an engineer undertaking for others work in connection with which he may make improvements, inventions, plans, designs, or other records, should enter into an agreement regarding their ownership.

Sec. 3. If an engineer uses information which is not common knowledge or public property, but which he obtains from a client or employer, the results in the form of plans, designs, or other records, should not be regarded as his property, but the property of his client or employer.

Sec. 4. If an engineer uses only his own knowledge, or information which by prior publication, or otherwise, is public property and obtains no engineering data from a client or employer, except performance specifications or routine information, then in the absence of an agreement to the contrary the results in the form of inventions, plans, designs, or other records, should be regarded as the property of the engineer, and the client or employer should be entitled to their use only in the case for which the engineer was retained.

Sec. 5. All work and results accomplished by the engineer in the form of inventions, plans, designs, or other records, that are outside of the field of engineering for which a client or employer has retained him, should be regarded as the engineer's property unless there is an agreement to the contrary.

Sec. 6. When an engineer or manufacturer builds apparatus from designs supplied to him by a customer, the designs remain the property of the customer and should not be duplicated by the engineer or manufacturer for others without express permission. When the engineer or manufacturer and a customer jointly work out designs and plans or develop inventions, a clear understanding should be reached before the beginning of the work regarding the respective rights of ownership in any inventions, designs, or matters of similar character, that may result.

Sec. 7. Any engineering data or information which an engineer obtains from his client or employer, or which he creates as a result of such information, may be considered confidential by the engineer; and while he is justified in using such data or information in his own practice as forming part of his professional experience, its publication without express permission is improper.

Sec. 8. Designs, data, records, and notes made by an employee and referring exclusively to his employer's work, should be regarded as his employer's property.

Sec. 9. A customer, in buying apparatus, does not acquire any right in its design but only the use of the apparatus purchased. A client does not acquire any right to the ideas developed and plans made by a consulting engineer except for the specific case for which they were made.

The Engineer's Relations to the Public and to the Engineering Profession

Sec. 10. It is desirable that the first publication concerning inventions or other engineering advances should not be made through the public press, but before engineering societies or through technical publications.

Sec. 11. It is unprofessional to give an opinion on a subject without being fully informed as to all the facts relating thereto and as to the purposes for which the information is asked. The opinion should contain a full statement of the conditions under which it applies.

Sec. 12. An engineer in responsible charge of work should not permit non-technical persons to overrule his engineering judgments on purely engineering grounds.

III. Use of Membership Designations and Institute Insignia

Sec. 13. The use of a membership designation, such as Fellow, Member, Associate, or Honorary Member, is a purely personal privilege of the individual member. It may be used with the member's name on stationery and in any ethical professional advertising. But a corporation, association, or firm may not itself use any membership designation because of the individual membership status possessed by a representative of a corporation, association, or firm.

Sec. 14. Insignia of the Institute, that is, any symbol such as an imprint of the badge design, or a heading such as "American Institute of Electrical Engineers," should be used only for Institute business and publications. The personal use of Institute insignia by a member should be limited to wearing an officially issued badge of the appropriate grade.

HISTORY OF THE CANONS AND CODE

The Institute Code

At the Milwaukee convention in May 1906, Dr. Schuyler Skaats Wheeler delivered his presidential address on "Engineering Honor." It was the sense of the convention that the ideas contained in this address should be embodied in a Code of Ethics for the electrical engineering profession, and to this end the following committee was appointed in October 1906:

Schuyler Skaats Wheeler, *Chairman*

H. W. Buck — Charles P. Steinmetz

In May 1907, the committee reported a code to the President and Board of Directors for discussion at the June convention at Niagara Falls. It was discussed and approved by the convention, and it was taken up by the Board of Directors on August 30, 1907, revised, printed, and submitted to the membership for suggestions to be sent to a new committee appointed by President Stott.

In June 1911, in accordance with a resolution of the Board of Directors, President Jackson reappointed a committee which was assisted by eighteen advisory members, as follows:

William S. Barstow	John W. Lieb, Jr.	Charles F. Scott
Louis Bell	C. O. Mailloux	Samuel Sheldon
John J. Carty	Ralph D. Mershon	William Stanley
Francis B. Crocker	Henry H. Norris	Lewis B. Stillwell
Dugald C. Jackson	Ralph W. Pope	Elihu Thomson
A. E. Kennelly	Harris J. Ryan	W. D. Weaver

This committee's work was presented in a report to the Board of Directors on February 9, 1912, when the code was tentatively adopted and the title of the committee and of the code was changed from that of Code of Ethics to Code of Principles of Professional Conduct. After a month's careful analysis and consideration of numerous suggestions from the advisory members of the committee and others, the completed code was adopted at the meeting of the Board of Directors on March 8, 1912.

On March 17, 1922, the Board of Directors adopted resolutions re-affirming adherence to the code, and providing that it shall be the duty of the Committee on Code of Principles of Professional Conduct to advise inquirers respecting questions of proper professional conduct, and to investigate and report upon any practice of a member of this Institute which might be prejudicial to the welfare of the Institute, the engineering profession, or the community.

Since 1912 the following have served as members of the Committee on Code of Principles of Professional Conduct:

C. A. Adams	H. B. Gear	M. Penn
P. L. Alger	Harold Goodwin, Jr.	W. M. Platt
R. B. Argersinger	Carl A. Hedin	H. T. Plume
A. H. Babcock	F. B. Jewett	Harris J. Ryan
Harry Barker	John F. Kelly	H. R. Sargent
H. H. Barnes, Jr.	W. B. Kouwenhoven	A. M. Schorn
C. R. Beardsley	W. S. Lee	R. F. Schuchardt
B. A. Behrend	John W. Lieb	George F. Sever
H. W. Buck	H. P. Liversidge	C. E. Skinner
H. V. Carpenter	A. M. MacCutchen	Harold B. Smith
H. P. Charlesworth	R. D. Maxson	Walter Charles Smith
L. W. Chubb	A. S. McAllister	R. W. Sorensen
Edith Clarke	R. D. Mershon	C. E. Stephens
Gano Dunn	E. B. Meyer	L. B. Stillwell
P. F. Evenson	W. E. Mitchell	John B. Taylor
D. D. Ewing	L. F. Morehouse	G. A. Waters
G. Faccioli	E. L. Morland	James S. Waters
R. S. Fields	S. H. Mortensen	Schuyler Skaats Wheeler
B. H. Flath	H. N. Muller	J. B. Whitehead
J. C. Forsythe	Farley Osgood	W. E. Wickenden
N. E. Funk	John C. Parker	H. S. Wynkoop

The Canons of the Engineers' Council for Professional Development

A project for a uniform statement of ethics to be formally adopted in the American engineering world was first organized under the auspices of the American Engineering Council, with Dugald C. Jackson as Chairman of a special committee. The Council was dissolved in 1940 but the Engineers' Council for Professional Development had come into existence and took on the responsibility for this committee which continued with Dr. Jackson as Chairman down to 1948. This committee was made up of a representative of each one

of the eight constituent societies of the Council plus the American Institute of Consulting Engineers.

The committee in 1942 came to agreement on a formulation of Canons of Ethics consisting of 31 items. This was approved by the Council and forwarded to the constituent societies with the request that each society through its Board should give the Council its views of the Canons. The American Institute of Electrical Engineers and the National Council of State Boards of Engineering Examiners approved the Canons in principle. The Council of the American Institute of Consulting Engineers advanced changes in phraseology and in arrangement of items, which statement was then referred to as the Alternative Draft. The American Society of Mechanical Engineers accepted the Canons in principle with a preference for the Alternative Draft. The American Society of Civil Engineers approved in principle a committee draft similar to the Alternative. The Engineering Institute of Canada approved a draft largely founded on the alternatives. In April 1947, the Committee of the Council adopted the statement of the Engineering Institute of Canada (which society had the benefit of the preceding years of discussion before making its formulation) with some slight modifications. The Executive Committee of the Council approved this statement and recommended to its constituent societies that it be adopted. The Council in October 1947, in accordance with the assent of seven of the eight constituent societies adopted the revised Canons as the official formulation for the engineering field, and recommended its adoption by the separate societies.

The Board of Directors of the American Institute of Electrical Engineers adopted the revised Canons on November 5, 1947, advising its Committee on Principles of Professional Conduct to revise the Institute's old Code to accord with such action.

The "Statement of Principles of Professional Conduct," as above printed, was recommended to the Directors by the 1949–1950 Institute Committee embodying the Canons and supplementing them with certain rules of business practice from the old code not embodied in the Canons. The Statement was adopted by the Directors on August 4, 1950.

The "Canons of Ethics for Engineers," Part I of this statement, printed on rag paper in a size, 9 inches by 14 inches, suitable for mounting, may be purchased from Engineers' Council for Professional Development, 29–33 West 39th Street, New York 18, N. Y., at a price of 50¢ each—35¢ in lots of ten or more. Please include remittance with order.

OF CURRENT INTEREST

New System of Handling Correspondence by Remote Control Dictation Is Announced

In a new approach to handling business correspondence, Thomas A. Edison, Inc., has developed a new system of "remote control" dictation. The TeleVoice System, as it is called, consists of from 1 to 20 modified telephones directly connected to a central recording instrument located near the secretary.

The recording instrument, called the Edison TeleVoicewriter, records the dictation received on plastic discs. Transcription of the dictated matter is accomplished with the standard disc.

The TeleVoice Stations (phone extensions) can be located any distance from the TeleVoicewriter. Each station gives the dictator every one of the services he needs to dictate, including a means of listening back to what he has said and the facility for recording corrections.

Unlike individual dictating machines, the dictator has only those functions to perform which are a direct part of actual dictation. The secretary takes care of changing the discs and index slips. Since the work is delivered to her by direct wire, her flow of work is even and messenger services are minimized. A positive warning signal in the form of a small red light on each phone goes on when the system is being used, making it unnecessary to pick up the receiver and listen to find out if all is clear.

The result is a well-integrated system for business dictation—a dictating system that because of its low cost (only half that of individual machines) makes possible instrument dictation service to every letter or memo writer even though his daily output may be very small.

TeleVoice Stations (extensions) are made in both desk-type and mount-type phones. On each phone base is just one button and the signal light. This button is used both for making corrections and for listening back. In the handle is a "talk switch" that is held down during dictation; it starts and stops the disc on the TeleVoicewriter recording instrument. The dictator records correction marks on the index slip by pressing the button located on the base of the TeleVoice extension while holding the "talk" switch down. To listen back the dictator presses the base button only. Length marks on the index slip are automatically recorded by "hanging up." While as many as 20 TeleVoice Stations can be wired to one TeleVoicewriter recorder, the average for commercial installations is ten.

A typical installation of Edison TeleVoice Stations for remote control dictation. Man in foreground is shown dictating at one of the TeleVoice Stations in the department pictured. A modified telephone instrument, the TeleVoice station provides the dictator with all the control he needs for dictation, and it automatically records the length of dictation on hanging up

William P. Lear Winner of the Collier Trophy for 1950

William P. Lear has been named the recipient of the 1950 Robert J. Collier Trophy for " . . . the greatest achievement in aviation in America during the previous year," by the National Aeronautic Association in Washington, D. C.

Mr. Lear, Chairman of the Board of Directors and Director of Research and Development of Lear, Inc., Grand Rapids, Mich., Los Angeles, Calif., and Elyria, Ohio, received the award from the President

Future Meetings of Other Societies

American Concrete Institute. 47th Annual Convention. February 20–22, 1951. St. Francis Hotel, San Francisco, Calif.

American Material Handling Society. Materials Handling Conference held concurrently with the National Materials Handling Exposition. April 30–May 4, 1951. International Amphitheatre, Chicago, Ill.

American Society for Testing Materials. Spring Meeting. March 5–9, 1951, Cincinnati, Ohio.

American Society of Tool Engineers. Annual Meeting. March 15–17, 1951, Hotel New Yorker, New York, N. Y.

Conference on Industrial Personnel. March 19–23, 1951, Columbia University, New York, N. Y.

Fourth Annual Conference for Protective Relay Engineers. March 26–28, 1951, Agricultural and Mechanical College of Texas, College Station, Tex.

Institute of Radio Engineers. Annual Convention. March 19–22, 1951, Waldorf Astoria Hotel and Grand Central Palace, New York, N. Y.

Institute of the Aeronautical Sciences. 19th Annual Meeting. January 29–31 and February 1, 1951, Hotel Astor, New York, N. Y.

Instrument Society of America. Conference being held by the Pittsburgh Section and the Carnegie Institute of Technology. March 28–29, 1951. Pittsburgh, Pa.

Midwest Power Conference. 14th Annual Conference. April 4–6, 1951. Sherman Hotel, Chicago, Ill.

National Association of Corrosion Engineers. March 13–16, 1951, Hotel Statler, New York, N. Y.

Pennsylvania Electric Association. Prime Movers Committee. March 8–9, 1951. Berkshire Hotel, Reading, Pa.

Pennsylvania Electric Association. Winter Meeting of Transmision and Distribution Committee. February 1–2, 1951, William Penn Hotel, Pittsburgh, Pa.

Society of Motion Picture and Television Engineers. Spring Convention. April 30–May 4, 1951. Hotel Statler, New York, N. Y.

Society of the Plastics Industry. Sixth Annual Technical Session. February 28 and March 1–2, 1951, Edgewater Beach Hotel, Chicago, Ill.

of the United States " . . . for his outstanding achievement in the development, perfection, application and production of the Lear F-5 Automatic Pilot and Automatic Approach Control Coupler System, which makes possible the safe landing of jet aircraft regardless of extreme weather or visibility conditions."

The Lear system consists of a small, lightweight, automatic pilot capable of controlling a supersonic jet fighter, and an automatic approach control coupler which hooks the jet plane onto the Government's standard Instrument Landing System beam. The All-Weather Flying Command of the United States Air Force at Patterson Field, under whose auspices Lear developed the automatic approach control coupler system, has rigorously tested it since 1949 under operating conditions, and found it to be a necessity in completing zero-zero weather landings, making all-weather interception operations practical.

The Lear F-5 automatic pilot is the first to be accepted for use in jet fighter-type aircraft, and has given the Air Force a solution to the problems of operationally safe night flight, blind flight, automatic tracking, and all-weather landing of these aircraft.

It is an electromechanical device which automatically holds an aircraft on any predetermined course at any altitude, and will also allow the pilot to make alteration of this course at will. Turns are co-ordinated, flying fast or slow or in any angle of climb or dive. It is made up of three main parts which closely parallel a human pilot's control system. The gyroscopes are the F-5's eyes; they sense any deviation from the course or altitude. The amplifier is the brain which controls the servomechanisms which are the muscles that apply the force to the control surfaces of the aircraft. There are three sets of eyes, three sets of brains, and three sets of muscles.

The Lear F-5 automatic pilot provides in addition three extras which monitor the operation. One is the automatic trim tab which keeps the manual trim tab adjusted to the position so that the main servomechanism has the least work to do, and solves the problem of airplane trimming so that whenever the F-5 is turned off, the jet does not dive or climb. Another controls the directional gyro so that it always points to the proper magnetic direction. This enables the ship to fly a straight magnetic heading. The third extra keeps the ship at any selected altitude. All these are supplemented by the two vital course steerers when making an automatic Instrument Landing System let-down to the runway, or automatic approach and landing. One of these keeps the jet on the localizer or horizontal path, and the other keeps it sliding down the vertical or glide path right to the runway.

The Lear F-5 autopilot as installed on the instrument panel of a Twin Beech showing controller and automatic approach control coupler. Lear Dual ADF-12 and Lear VHF receiver and transmitter combined with low-frequency range and broadcast receiver is shown above on the instrument panel

Karl T. Compton Presented the Hoover Medal for 1950

Karl T. Compton, Chairman of the Corporation of the Massachusetts Institute of Technology, Cambridge, Mass., has been awarded the Hoover Medal for 1950. The Medal, established through a trust fund created by the gift of Conrad N. Lauer, is to be awarded periodically by a Board of Award, composed of representatives of the national societies of Civil, Mining, Mechanical, and Electrical Engineers, "to a fellow engineer for distinguished public service." The first award was made in 1930 to President Herbert Hoover to commemorate his civic and humanitarian achievements. Doctor Compton is a fellow of the AIEE.

Alfred Noble Prize Awarded to Kochenberger for Best Paper

The Alfred Noble Prize for a technical paper of exceptional merit this year was awarded to Ralph J. Kochenburger, assistant professor of electrical engineering, University of Connecticut, Storrs, Conn., and a member of the American Institute of Electrical Engineers, for his outstanding research paper "A Frequency-Response Method for Analyzing and Synthesizing Contactor Servomechanisms."

This prize was established in 1929 and consists of a cash award from the income of a fund contributed by engineers and others in honor of the late Alfred Noble, Past President of the American Society of Civil Engineers and of the Western Society of Engineers, for the purpose of perpetuating his name and achievements.

The award is made to a member of any grade of the AIEE, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, or the Western Society of Engineers, for a technical paper of exceptional merit accepted for publication in any of their technical publications, provided the author has not passed his thirty-first birthday at the time the paper is submitted. The award is based on papers published by each society within the 12 months preceding June 1 of each year. Papers prepared by joint authors are not eligible.

The amount of the prize is determined by resolution of the Board of Directors of the American Society of Civil Engineers. The award this year is approximately $350.

Vannevar Bush Receives John Fritz Medal for 1950

The John Fritz Medal for 1950 has been awarded to Vannevar Bush, President of the Carnegie Institution of Washington, Washington, D. C., "for his outstanding scientific

contributions to his country and to his fellow men."

The Medal is awarded annually by a board composed of four representatives of each of the four national engineering societies, the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, and the American Society of Civil Engineers, for notable scientific or industrial achievements, regardless of nationality or sex. It was established by professional associates and friends of John Fritz on August 21, 1902, to perpetuate the memory of his achievements in industrial progress. The first award of the Medal was made to John Fritz at a dinner given on his 80th birthday August 21, 1902.

Former recipients have included George Westinghouse, Alexander Graham Bell, Orville Wright, Thomas A. Edison, Herbert Hoover, Charles F. Kettering, Alfred Noble, and Guglielmo Marconi.

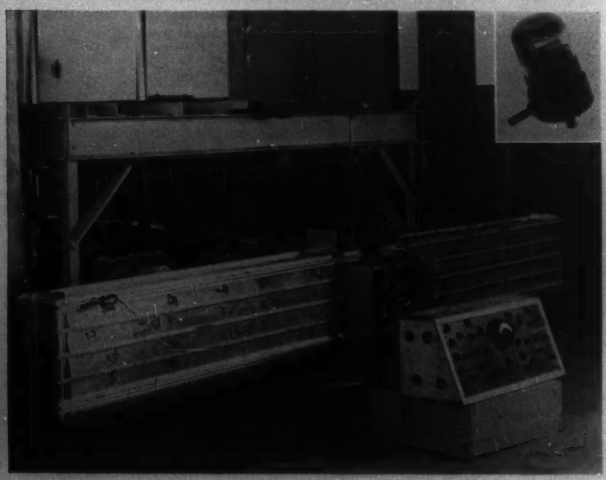
Improved Ramberg Vacuum-Tube Accelerometer Developed by NBS

Recent research in the Engineering Mechanics Section of the National Bureau of Standards (NBS) has resulted in an improvement of the Ramberg vacuum-tube accelerometer which NBS developed in 1946 for the Navy's Bureau of Aeronautics with the co-operation of Sylvania Electric Products, Inc. The new pickup provides more sensitive and reliable acceleration measurements than did the earlier version which, despite slight erratic changes during its operation, has been successfully applied to both field and laboratory acceleration measurements. Among such uses have been acceleration measurements on pilot ejection devices for high-speed aircraft, in landing impact tests for model aircraft, as well as on aircraft in actual flight.

The vacuum-tube acceleration pickup is a twin-diode consisting of a fixed, indirectly heated cathode and two plates, one on each side of the cathode. The plates are elastically mounted so that they will be deflected if the base of the tube is accelerated in a direction perpendicular to the plane of the plates. The new model differs from earlier versions in having stops to limit the motion of the plates, support rods 0.010 inch in diameter to increase the sensitivity of the tube, and a second getter.

The primary design requirement met by the Ramberg vacuum-tube accelerometer is its provision for an electric signal of sufficient strength to drive directly a high-frequency recording galvanometer and at the same time have a relatively high natural vibration frequency. In the operation of the original model erratic changes or "zero shifts" in its balance point were sometimes encountered. The source of this difficulty has been eliminated in the new model. The zero shift, resulting from excessive accelerations to the pickup while handling and installing, is prevented by stops which were added to limit the plate excursion and thus prevent overloading. "Zero drift," believed to be due to small fluctuations in the cathode electron emission, has been effectively reduced by three steps: 1. the accelerometer was given an aging treatment which made its emission nearly constant; 2. two "getters" instead of one were used to improve the electrical characteristics; 3. the sensitivity was increased by a factor of 25 to make the remaining random output negligible compared with the output due to acceleration.

Because of promising results obtained with both the original and improved tube, an extended developmental project on the fundamentals of acceleration measurements is now under way as part of the NBS program on basic instrumentation, which is co-operatively supported by the Office of Naval Research, the Office of Air Research, and the Atomic Energy Commission. The objectives of this project are to obtain accelerometers having a greater range of acceleration measurement, higher output voltages, and damping of the natural frequency response.



The improved Ramberg vacuum-tube accelerometer (see inset) being used for measuring the amplitude of vibration at a natural frequency of this structural model of an airplane wing. The accelerometer at the wing tip is used to keep the vibration at a constant level; the other accelerometer is moved from station to station to measure the variation of vibration amplitude with position along the length of the model

New Electrical Components Developed by Air Force

The development of a new high-temperature tantalum capacitor with longer life and better electrical characteristics was announced recently by Electronic Subdivision engineers at Air Materiel Command Headquarters, Wright-Patterson Air Force Base, Dayton, Ohio.

Operation of the new unit is now possible from −60 degrees centigrade to +175 degrees centigrade. This is a significant performance advance over presently available electrolytic capacitors which are not operable beyond a range of −40 degrees to +85 degrees centigrade. The new capacitor also boasts a shelf life of from five to eight years as compared to the normal 12- to 18-month life of the currently used capacitor.

At −60 degrees centigrade, less than 15 per cent of the capacitance is lost in the new piece of electronic equipment. This is due to the tantalum electrodes on which is formed tantalum oxide, a more stable product than the aluminum oxide formation used on old-type capacitors. From 50 to 70 per cent of the electrical capacitance was lost in the aluminum electrolytic capacitor at −40 degrees centigrade.

A precision-type resistor that hits new peaks in stability and efficiency also has been developed by the Air Materiel Command's Electronic Subdivision. Ordinary wire-wound or composition resistors have a temperature coefficient ranging from 1 to 20 per cent, depending on environment. The new, more stable high-temperature deposited carbon resistor varies less than 0.1 per cent. A special high-temperature protective paint, which acts as an oxygen barrier, enables full lead operation at temperatures ranging up to 200 degrees centigrade. The old type resistors could not operate in temperatures higher than 70 to 85 degrees centigrade.

The new resistor is also lighter and stronger than its predecessors. A ceramic base that replaces the old type porcelain base bolsters strength, although the new resistor is much smaller than either the wire-wound or composition type.

Election of Ralph J. Cordiner As New G.E. President

The election of Ralph J. Cordiner of New York as President of the General Electric Company to succeed Charles E. Wilson, who has been named Chairman of the new Defense Mobilization Board, was

announced recently. The retiring president completed 51 years of continuous service with General Electric in November. Starting in 1899 as a messenger boy with the Sprague Electric Company, later to become a part of General Electric, he rose to the presidency in 1939. He served as vice-chairman of the War Production Board in Washington from 1942 until 1943, and then was named executive vice-chairman with full authority over all war production, serving in that post until 1944.

He resigns also as Chairman of the Board of General Electric Supply Corporation and as a member of the board of directors of International General Electric Company and the Guaranty Trust Company.

Mr. Cordiner was graduated from Whitman College in 1922. His first position after graduation was as commercial manager of a division of the Pacific Power and Light Company. In less than a year he was offered a position with the Edison General Electric Appliance Company with headquarters in Portland. Five years later he became Northwest manager in Portland and in 1930 moved to San Francisco to become Pacific Coast division manager.

When the heating device section of the Edison General Electric Appliance Company was transferred from Chicago and consolidated with General Electric's Appliance and Merchandise Department at Bridgeport in 1932, Mr. Cordiner went with the section as manager and chairman of the management committee. Two years later he was appointed assistant manager of appliance sales, and in 1935 became manager of the radio division. A year later he was promoted to assistant manager of the Appliance and Merchandise Department, and in January 1938 succeeded Mr. Wilson as manager of the department.

In 1942, Mr. Cordiner entered government service as director-general of war production scheduling and vice-chairman of the War Production Board. He rejoined General Electric as assistant to the president in 1943 and was elected Vice-President in February 1945. He assumes immediately his new duties as President.

Applications for 1951 Sloan Fellowships Due in February

Fourteen young business executives will be awarded Sloan Fellowships in 1951 for participation in an Executive Development Program at Massachusetts Institute of Technology (MIT). These fellowships, awarded to outstanding young executives in a nation-wide competition, cover a year of advanced study in economics and business administration at MIT and are aimed at preparing men for higher executive responsibility.

This program of broad and high level education toward managerial leadership, initiated 20 years ago by MIT's Department of Business and Engineering Administration, was the pioneer program of its kind. Its continuance has been made possible by grants of funds from the Alfred P. Sloan Foundation and by the support of companies who sponsor outstanding young men and provide a leave of absence for a year.

Sponsorship by an employer is a prerequisite of this program. The candidates will be drawn from both large and small companies in various types of industry throughout the country. The winners of the fellowships will participate in a special program consisting of seminars, classes, and field investigations aimed not only at increasing technical managerial skill, but also their understanding of the social and economic implications of their work.

Applications for the awards must be made by February 24, 1951. Recipients will be selected on a competitive basis by MIT after consideration of the applicants' records and references, and consultation with their employers. Awards range up to $3,720 for married men and up to $2,720 for those who are single. Fellows will be in residence at MIT in Cambridge from June 1951 to June 1952. Applicants must be between the ages of 30 and 35 and have at least five to ten years of industrial experience, part of it in an executive capacity.

The largest recorded value of short-circuit current, the equivalent of 12,000,000 kva symmetrical 3-phase, was used in testing this single-pole unit of one of the 13 oil circuit breakers at the Grand Coulee Dam project

Short-Circuit Tests Set New Record at Grand Coulee Dam

A new record for short-circuit current was set recently during a series of tests conducted by the General Electric Company and the United States Bureau of Reclamation at Grand Coulee Dam. The tests were made on a single-pole unit of one of the 13 10,000,000-kva 230-kv low-oil-content impulse-type oil circuit breakers now installed in the right-hand switchyard of the Grand Coulee project. The generating capacity of 12 of the 14 108,000-kw generators at Grand Coulee, plus the available capacity of other stations of the Northwest Power Pool, were introduced into the tests to produce the largest value of short-circuit current ever recorded, the equivalent of 12,000,000 kva symmetrical 3-phase.

Even this enormous amount of short-circuit current was interrupted by the 10,000,000-kva circuit-breaker unit within its rated interrupting time of three cycles without any sign of distress.

A total of 12 interrupting- and 24 line-dropping tests were made, all of which were entirely successful. The interrupting tests ranged from 5,000,000 to 12,000,000 kva and four of them, ranging from 6,000,000 to 9,000,000 kva, were high-speed reclosing tests with reclosing times between 8.75 and 9.2 cycles. The line-dropping tests, all of which were accomplished without the occurrence of a single restrike, were made with from 100 to 300 miles of 230-kv transmission line. Inspection afterward revealed that all parts of the circuit breaker were in condition to continue normal operation and the unit could have withstood many additional tests.

An elaborate instrumentation equipment devised by the General Electric Company's Switchgear Divisions' Laboratory was used to record the tests in much more complete form than has been possible previously.

New Facsimile System Developed by RCA for Oak Ridge Laboratory

A test model of a new high-speed, long-distance facsimile system, developed by the Radio Corporation of America (RCA)

Laboratories, Princeton, N. J., under contract with the Atomic Energy Commission, has been installed at the Oak Ridge National Laboratory for providing full reference library service to outlying research laboratories.

The new system incorporates several innovations in the field of facsimile reproduction. The reader-transmitter will scan printed copy or drawings on flat surfaces such as book pages and will make direct enlargements of material in small type by any ratio up to four to one. The copy bed can handle individual sheets or books up to three inches thick. The signal is transmitted over an ordinary telephone line and the recorder will reproduce clear, highly legible black-on-white copy at a speed of 15 linear inches or 120 square inches per minute.

Operational tests to be started at Oak Ridge immediately will indicate to what extent existing library services at the Laboratory can be expanded without greatly increasing the outlay for new books and particularly scarce and expensive sets of bound scientific periodicals. The system also will prevent possible contamination of books and journals in laboratories using radioactive materials.

At the present time at Oak Ridge, more than a score of separate research and production facilities scattered over a wide area require library services. If the new facsimile service proves useful, it may be possible to consolidate many of these library services into larger, more adequate units.

A cathode-ray flying-spot scanner at the sending unit is the most important innovation. The 5-inch cathode-ray tube directs a tiny spot of light through a focusing lens to "read" the copy in a thin line from left to right. The reflected light from the copy is picked up by a bank of four photomultiplier tubes which convert the varying light impulses into normal electric facsimile signals.

The copy bed automatically moves the copy forward under the flying-spot cathode-ray tube. The length of the scanning line on the copy can be adjusted from $2^1/_{16}$ to $8^1/_2$ inches by simply turning a knob. This automatically adjusts the lens to maintain the proper focus and the same adjustment changes the speed of the copy bed to maintain the correct scale.

The receiver, or recorder, also incorporates several new mechanical and chemical features to simplify operation and to supply a permanent print of the transmitted material. The electrolytic process used in recording eliminates photodeveloping and printing and avoids clogging and corrosion of previous electrolytic methods. The paper is moistened no more than is absolutely necessary, and as it passes out of the machine it is completely dried. Ultraviolet light fixes the chemicals so that neither the printing nor the background will fade. The clogging and corrosive action of the chemical solution is eliminated by keeping separate the two components until applied to the paper.

Westinghouse Gets $20,000,000 Wind Tunnel Order

The Westinghouse Electric Corporation has received an order from the United States Air Force for $20,000,000 worth of electric equipment for a new wind tunnel to test full size jet engines, guided missiles, and wing sections and fuselages of aircraft.

The wind tunnel will be built at the Arnold Engineering Development Center, Tullahoma, Tenn. The Center houses important aeronautical research facilities available not only to the Air Force, Army, and Navy but also to all parties in government, industry, and science interested in aircraft development. It was renamed recently in honor of the late General H. H. "Hap" Arnold, wartime head of the Army Air Force.

Of four big electric motors to be built for the new tunnel, two will be the most powerful in the world, exceeding the 65,000-horsepower rating of the motors now in service at Grand Coulee Dam in the state of Washington. The motors and switchgear for their control will be built at the Westinghouse plant in East Pittsburgh, Pa.

The Sunnyvale, Calif., plant will make a big air compressor to push air through the tunnel at speeds up to and above the speed of sound. The compressor will be the world's largest rotating machine.

"Anaerobic Permafil" New Material Developed by G.E.

A material which remains liquid as long as a stream of air bubbles through it, but which hardens in a few minutes when away from air, has been developed in the chemistry divisions of the General Electric Research Laboratory. Its properties are thus opposite to those of paint, which hardens when exposed to air.

This new material is able to penetrate extremely small cracks before hardening. Thus, a possible application is a tight seal for stopping nearly invisible leaks, or a "pipe dope" for sealing threaded unions. The laboratory scientists responsible for the new development are Dr. Robert E. Burnett and Birger W. Nordlander.

They call the substance "anaerobic permafil," borrowing a word from the biologists. The term "anaerobic" means "non-airliving," and it is used by bacteriologists to designate organisms that remain inactive in the presence of air, but which thrive and propagate when air is absent.

Anaerobic permafil remains liquid as long as it is aerated. When away from air it solidifies quickly, without heating, or adding catalysts and accelerators. When two metal strips are coated lightly with it and clamped together the joint will support ten pounds after ten minutes. After 20 hours, it will hold 100 pounds. If still faster hardening is desired, the permafil may be heated up to 212 degrees Fahrenheit and solidification takes place in a minute or less.

Engineering Curricula and Programs Accredited by ECPD

The work of accrediting undergraduate engineering curricula and the programs of the technical institute type in the United States has been continued by the Educational Committee (formerly the Committee on Engineering Schools) of the Engineers Council for Professional Development (ECPD). The work of accreditation has received wide acceptance by the schools, the profession, and the public.

As of October 20, 1950, ECPD had accredited 656 engineering curricula representing 142 different schools with accredited curricula. Some 50 programs of the technical institute type have been accredited in 19 technical institutes.

The complete list of accredited undergraduate engineering curricula by institutions and by curricula as well as the list of accredited programs of technical institute type has been made available by ECPD in a 20-page pamphlet with statements of the objectives and procedure of accrediting; this list may be purchased at a price of 25¢ each. Please address all orders to ECPD, 29–33 West 39th Street, New York 18, N. Y., and include remittance with order.

Armour Research Foundation to Offer Fellowships in 1951

Armour Research Foundation of Illinois Institute of Technology is offering a number of industrial research fellowships in physics, chemistry, metallurgy, ceramics, mechanics, and electrical engineering to begin in September 1951. Those persons awarded fellowships will attend Illinois Institute of Technology half-time and work in the Research Foundation half-time in a graduate program leading to advanced academic degrees. They are employed full-time by the Foundation during the summer.

Fellowships begin at the start of the school semester and continue through the summer for approximately 21 months until the end of the second academic year. Awards are made on a competitive basis to United States citizens under 28 years of age holding a bachelor's degree from an accredited engineering or scientific school or liberal arts college with a major in the sciences.

In addition to tuition, fellows receive $150 a month during the first academic year, $275 a month and a 2-week vacation during the summer, and $175 a month during the second academic year. The Foundation awarded five fellowships in 1950. Application forms may be obtained from the Office of Admissions, Graduate School of Illinois Institute of Technology, Chicago, Ill. Applications received prior to March 15 will be given first consideration.

Indian Engineers Return Home After Training Course in U.S.

After a ten months' visit and intensive training course in this country, a group of 11 engineers sent here by the Government of India have returned home to apply American methods to a vast new power project in their native land. They will form the chief members of the engineering staff which will operate the new Bokaro Steam Power Plant in the Damodar Valley project, one of the largest ever undertaken in the East.

The training of the group during their stay here was supervised by The Kuljian Corporation of Philadelphia, Pa., to whom the Indian Government has awarded the contract for the design, engineering, and construction of the Bokaro Steam Power Plant. In addition to their course of training

at the Kuljian headquarters in Philadelphia, the engineers studied operating methods at over a dozen large utility plants in the East and Middle West. They also visited the General Electric plant in Schenectady, and other manufacturing plants supplying the major equipment for the Bokaro Station.

On their return to Bokaro, the engineers will work closely with the Kuljian staff now supervising the construction of the plant. It will include a series of eight dams along the Damodar River. The objects are very similar to those of our Tennessee Valley Authority project: to provide the benefits of irrigation, flood control, and cheap power to an immense area. For one year after it is completed, the plant will be operated by American personnel in the Kuljian Corporation's employ. Then the operation of the plant will be turned over to the Indian engineers.

Faith of the Engineer. Printed statements of "Faith of the Engineer" on rag paper in a size 17 inches by 22 inches suitable for mounting are available in a limited quantity from the Engineers' Council for Professional Development, 29–33 West 39th Street, New York 18, N. Y., at a reduced price of $2.00. Please include remittance with order.

Illinois Engineering Council Elects Officers

Alois W. Graf, Chicago patent lawyer and member of the Institute of Radio Engineers and the Illinois Society of Professional Engineers, was named president of the latter organization for 1951. G. C. Laughlin of the Commonwealth Edison Company and The American Society of Mechanical Engineers is first Vice-President. Second Vice-President is R. A. Lonier of the Illinois Association of Highway Engineers. John A. Harrington of the Illuminating Engineering Society is Secretary-Treasurer. K. V. Glentzer of AIEE, R. R. Bartelsmeyer of Belleville and the Illinois Association of County Superintendents of Highways, and Norman Gundrum of Springfield and the American Society of Civil Engineers, are members of the Executive Committee.

The Illinois Engineering Council, composed of 16 engineering societies, is active in civic and governmental matters pertaining to the engineers' professional interests. It makes recommendations for appointments to the examining boards for registration under the Structural and Registered Professional Engineering Acts.

School of Reactor Technology Receiving Applications

Applications are now being received by the Oak Ridge School of Reactor Technology for enrollment in the 1951–52 session, beginning September 10, 1951. This school was established at the Oak Ridge National Laboratory in March of 1950 under sponsorship of the United States Atomic Energy Commission (AEC). Its purpose is to train engineers and scientists in the field of reactor theory and technology, in preparation for their employment in this field by the AEC or its contractors.

The Oak Ridge School of Reactor Technology will enroll students of outstanding qualifications who hold, or will receive by September 1951, bachelor's or master's degrees in chemistry, engineering, metallurgy, or physics. A limited number of recent college graduates will be accepted under Category A in the status of student-employees of the Oak Ridge National Laboratory, and will be paid a monthly stipend for a 12-month period, beginning September 1951.

Provision is also made for trainees sponsored by government agencies and industrial organizations connected with or interested in the AEC reactor development program, Category B. Applications for enrollment under this category must be made by the firms or agencies employing the applicants. Such students remain on the payrolls of their home organizations.

Much of the material presented in the curriculum of the Oak Ridge School of Reactor Technology will be classified; hence, all enrollments are contingent upon a personnel security investigation.

Men trained in chemistry, engineering, metallurgy, or physics are much in demand in the reactor development program. It is the purpose of the Oak Ridge School of Reactor Technology to provide engineers and scientists with sufficient background in reactor technology and allied subjects to become effective as research, development, and design personnel.

Further information and application forms may be obtained by writing to the Director, Oak Ridge School of Reactor Technology, Post Office Box P, Oak Ridge, Tenn. Category for which application is requested must be specified. These applications must be filed with the director of the school by March 1, 1951. Announcements of appointments will be made in April 1951.

Critical Shortage of Men In Field of Engineering

The success of America's industrial mobilization program is menaced by shortages of engineers, with the situation held "desperate" in some plants. Critical scarcities exist in the electronic, aviation, power equipment, ordnance, and machine tool industries.

A 4-point program to remedy the situation was recommended to the National Security Resources Board by the Engineering Manpower Commission of the Engineers Joint Council.

1. The registration by Selective Service of every man up to the age of 70 who has a bachelor's degree with a major in one of the critical fields of engineering, or who is enrolled in a program of training leading to a bachelor's or higher degree in one of these fields, or who is employed in one of these fields.

2. The establishment of a National Engineering Personnel Board whose duties shall be to review registrations, to establish criteria for inclusion in a "Reserve," to classify the registrants, and to make selections with critical skills for military, civil defense, and industrial allocation. This Board shall advise the President as to critical needs, allocations, and so forth, and shall administer the Reserve.

3. The Reserve shall be made up of registrants with special skills who have been selected by the National Engineering Personnel Board. The service or allocation of registrants in the Reserve shall be under the direction of National Engineering Personnel Board.

4. The need for technical personnel is so great that the Engineers Joint Council Engineering Manpower Commission believes that every effort should be made to reinforce the technical man power of industry through suitable auxiliary training similar to that of the Engineering, Science, Management War Training Program of the last war.

Infrared Cooking Is Forecast for the Future

Infrared cooking in household ranges is made practical for the first time through the advent of new high-wattage, gold-reflector heat lamps, which employ a new type of heat-resistant glass. The infrared cooking lamps, which are expected to go into commercial production within a short time, were developed by Sylvania Electric Products, Inc., New York, N. Y.

The new lamps are being planned for 1,250 watts, and are intended for either original equipment or conversion units. Advantages claimed for the new lamps are instantaneous heat output, a pleasant ruby-red glow which shows when the lamps are burning, a smooth level surface, easier cleaning, and faster action when small quantities of food are being cooked.

National Bureau of Standards Celebrates Its Semicentennial

The year 1951 marks the 50th anniversary of the National Bureau of Standards (NBS). A large number of the principal scientific and technical organizations of the nation, in recognition of the role of the Bureau in science, have planned meetings in Washington in 1951 to honor the Bureau's semicentennial. Some of the meetings have regularly been held in Washington in the past; most of them were planned for Washington by the societies in view of the Bureau's semicentennial.

Created by Act of Congress on March 3, 1901, NBS is the principal agency of the Federal Government for fundamental research in physics, mathematics, chemistry, and engineering. Thus the Bureau's activities are largely concerned with the physical sciences although the close interrelationships of the major fields of science preclude drawing sharp lines of distinction.

Engineering Societies Personnel Service, Inc. There are many executive and engineering opportunities available for which the Service does not have the personnel to recommend. Registration of men available is very low; therefore, if unemployed or seeking a better opportunity, contact the nearest office of the Engineering Societies Personnel Service, Inc., New York, Chicago, Detroit, or San Francisco.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Waves of all Velocities

To the Editor:

The velocity term contained in Mr. Slepian's equations 3 (Letters to the Editor, *EE, Jan '51, p 93*) is rather all-inclusive for it includes what are commonly referred to as phase and group velocities in addition to the velocity of propagation. The velocity of propagation which is perpendicular to the wave front, or the energy velocity as it is sometimes called, is the one which does not exceed c. Furthermore, the velocity of propagation is independent of the choice of axes. Thus in Dr. Slepian's equation 6, where the x axis has been rotated through an angle, we see that the velocity in the x' direction is now greater than c. However, the velocity in the x' direction is not the velocity of propagation, but rather it is the velocity of a point of constant phase, or phase velocity of the wave. The velocity of propagation is still directed along the x axis, and still equal to c. Indeed, if the x axis were rotated through an angle approaching 90 degrees, the phase velocity would approach infinity, yet the velocity of propagation would remain the same. Hence, the whole discussion is dependent upon the definition of velocity. From this I concede the following:

1. All electromagnetic waves in free space have a velocity of propagation equal to c, the velocity of light in a vacuum.
2. All electromagnetic waves in free space may have phase velocities not equal to c.

If v stands for either 1 or 2, then electromagnetic waves in free space exist with any and all velocities v.

Mr. Slepian's Electrical Essays are a credit to *Electrical Engineering*. I shall look forward to reading more of them.

EDWIN L. PETERSON (Student Member)

(Tulane University, New Orleans, La.)

To the Editor:

Mr. Peterson is quite right in saying that "the whole discussion is dependent upon the definition of velocity." That is the major point of my Letter to the Editor (*EE, Jan '51, p 93*) in which I defined velocity only for such waves as could be put into the mathematical form

$$u = f(x - vt, y, z) \qquad (1)$$

and for such waves, the velocity is defined as having magnitude v, and having the x direction.

There will be waves which cannot be expressed in the form of equation 1, and for such waves the velocity is undefined.

Mr. Peterson seems now to admit that the electromagnetic wave which I used as an example and which was expressed in equation 1 is a proper and satisfactory wave, and that the v in this equation may have any and all values.

But now Mr. Peterson discovers that there are two velocities, a "phase velocity" and a "propagation velocity," but in spite of his having stressed the need for explicit definition of the term velocity, he fails to give a definition of these two velocities. Presumably, he identifies his "phase velocity" with the v of my essay, and permits it to have any and all magnitudes. But how is his "propagation velocity" defined? For the wave equation 1 which presumably has the "phase velocity" v, how is the "propagation velocity" to be determined?

I am very pleased that Mr. Peterson enjoys my essays, and that they inspired this little discussion.

J. SLEPIAN (F '27)

(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Composite System of Units

To the Editor:

Science has long recognized the similarity of behavior between electrical and subatomic particles. Our delay in gaining the necessary knowledge to apply atomic energy to the creation of more enduring things than bombs is largely due to the fact that our electrical technique has thus far been satisfied with results that are only approximately exact. In the subatomic field, the utmost precision is required.

We are now currently using four different systems of base units in the electrical field; practical, electromagnetic, electrostatic, and rationalized meter-kilogram-second units. Tables have been prepared with which to convert results in terms of one system into equivalent expressions in either of the other systems. This situation could be simplified if we had a composite base in which all these units could be expressed.

To make my meaning clear, let us use the subscripts m and s for the electromagnetic and electrostatic units respectively in stating their relation to the corresponding practical units.

With current technique

$$R = R_m(10^{-9}) = R_s(9\times10^{11})$$
$$I = I_m(10) = I_s(1/3\times10^{-9})$$
$$E = E_m(10^{-8}) = E_s(3\times10^{2}),$$
$$R_m/R = 10^{9},\ R/R_s = (9\times10^{11}),$$
$$R_m/R_s = (3\times10^{10})^2$$
$$I_m/I = 10^{-1},\ I/I_s = (1/3\times10^{-9}),$$
$$I_m/I_s = (1/3\times10^{-10})$$
$$E_m/E = 10^{8},\ E/E_s = (3\times10^{8}),$$
$$E_m/E_s = (3\times10^{10})^2$$

It is obvious that there are at least two important facts that are inconsistent with our basic definitions in these values.

(1) abvolts/statvolts = (3×10^{10})
abamperes/statamperes = $1/(3\times10^{10})$
abohms/statohms = $(3\times10^{10})^2$

(2) Converting watts into ergs per second

$$EI(10^{7}) = (E\times10^{8})(I\times10^{-1}) = E_mI_m$$
$$EI(10^{7}) = (E/3\times10^{-8})(3I\times10^{9}) = E_sI_s$$

If we could use the speed of light as our composite base and define it

1 photosecond = (3×10^{10}) = the distance in centimeters that each photon moves in one second

we could restate our basic symbols as follows:

$$R = R_m(10^{-9}) = R_s(3\times10^{9})$$
$$I = I_m(10^{-1}) = I_s(3\times10^{9})$$
$$E = E_m(10^{-10}) = E_s(3\times10^{9})^2$$
$$R_m/R = 10^{9},\ R/R_s = (3\times10^{9}),$$
$$R_m/R_s = (3\times10^{18})$$
$$I_m/I = 10^{8},\ I/I_s = (3\times10^{8}),$$
$$I_m/I_s = (3\times10^{16})$$
$$E_m/E = 10^{18},\ E/E_s = (3\times10^{9})^2,$$
$$E_m/E_s = (3\times10^{18})^2$$

Converting watts into ergs per second

$$EI(10^{7}) = (E\times10^{18})(I\times10^{8})(10^{-17}) =$$
$$E_mI_m(10^{-17})$$
$$EI(10^{7}) = (E/9\times10^{-9})(I/3\times10^{-9})$$
$$(27\times10^{18}) = E_sI_s(27\times10^{18})$$

$$1 = \frac{EI(10^{7})}{EI(10^{7})} = \left(\frac{E_m}{E_s}\right)\left(\frac{I_m}{I_s}\right)\left(\frac{10^{-17}}{27\times10^{18}}\right) =$$
$$(3\times10^{10})^2(3\times10^{10})\left(\frac{1}{27\times10^{36}}\right)$$

IRVIN J. OSBORNE

(1419 West 25th Street, Los Angeles 7, Calif.)

Social Responsibility in Science

To the Editor:

Dean W. B. Kouwenhoven in his article "Obligations of the Engineer" (*EE, Dec '50, p 1057*) states that we engineers should become aware of our responsibility to others. Here are his words: "Since the last crisis that threatened our civilization the engineers and scientists have gone right ahead creating new devices without regard to their effect on our world."

Last year a group of scientists and engineers deeply concerned at the increasing use of science for destructive ends met and formed the Society for Social Responsibility in Science. One of the primary aims of this group is to create an awareness among scientists and engineers of the uses to which their work is put. The society invites inquiry.

NORMAN E. POLSTER (A'41)

(Leeds and Northrup Company, Philadelphia 44, Pa.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been pre-

rented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

BASIC ELECTRICAL MEASUREMENTS. By M. B. Stout. Prentice-Hall, Inc., New York, N. Y., 1950. 504 pages, illustrations, diagrams, charts, tables, 8½ by 5⅜ inches, linen, $7.75. This book is devoted to selected methods and instruments used most frequently to measure electrical phenomena. The principles, construction, and use of galvanometers, potentiometers, a-c bridges, and other measuring circuits and ancillary equipment are discussed. Two chapters deal with magnetic measurements and electric indicating instruments. Introductory material covers such topics as electrical units, experimental procedures, and aids to computation. Selected references and problems are included at the end of most of the chapters.

BIBLIOGRAPHY AND ABSTRACTS ON ELECTRICAL CONTACTS, 1949 Supplement (Technical Publication Number 56-F), prepared by A.S.T.M. Committee B-4 on Electrical Heating, Resistance, and Related Alloys, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 25 pages, 9 by 6 inches, paper, $0.75. This sixth supplement to the original bibliography of 1944 provides an approach to the latest information on the subject. There are more than 100 items, mainly from 1948 and 1949, although a few previously unlisted items from earlier years are included.

CAPACITORS FOR INDUSTRY. By W. C. Bloomquist, C. R. Craig, R. M. Partington, and R. C. Wilson. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1950. 246 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $4.50. Of interest to industrial plant engineers and electricians, utility power salesmen, consulting engineers, and industrial power application engineers, this book provides practical capacitor application data in tabular and curve form. In most cases, the answer can be obtained directly without the solution of the right triangle or the use of complex algebra. Numerous examples are included illustrating the use of data and, where necessary, the step-by-step procedure for the solution of practical problems.

COMMERCIAL MOTOR TRANSPORTATION. By C. A. Taft. Richard D. Irwin, Inc., 3201 South Michigan Avenue, Chicago 16, Ill., 1950. 413 pages, illustrations, diagrams, charts, maps, tables, 9¼ by 6 inches, fabrikoid, $6.65. This book is a broad treatment of the motor carrier industry which provides students of transportation and those concerned with truck and bus operations with a comprehensive coverage of the field. Part I outlines the scope of the industry and of the highway system. Part II covers the property-carrying aspects of the industry, Part III is devoted to passenger-carrying operations, both local and intercity. Questions and problems are collected at the ends of the chapters, and a bibliography is included.

DESIGN OF ELECTRICAL APPARATUS. By J. H. Kuhlmann. Third edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 512 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6.50. Practical methods are presented for the design of electric apparatus, with explanations of the theory, procedure, and limits of design. Changes in this third edition include a revision of design constants and limits, the plotting of the characteristic curves of electrical sheet steels on semilogarithmic paper, the enlargement of the copper tables to include new wire insulating materials, new values of insulation thickness, a review of multiplex windings, and many new methods for determining electrical and mechanical characteristics.

ELECTROMAGNETIC WAVES AND RADIATING SYSTEMS. By E. C. Jordan. Prentice-Hall, New York, N. Y., 1950. 710 pages, diagrams, charts, tables, 8¾ by 5¾ inches, linen, $10.50. Intended for use by senior and graduate electrical engineers and physicists, this textbook considers the theory and applications of electromagnetic radiation and propagation. A review of fundamental theory is followed by the presentation of more advanced material on electromagnetic waves. Transmission lines, wave guides, and antennas are discussed as well as ground-wave and sky-wave propagation. A bibliography and problems follow most of the chapters.

ELECTRON MICROSTRUCTURE OF STEEL, First Progress Report, Subcommittee XI on Electron Microstructure of Steel, A.S.T.M. Committee E-4 on Metallography, June, 1950. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 49 pages, illustrations, 9 by 6 inches, paper, $1.35. Results are presented of studies on the electron microstructure of a eutectoid steel. It contains 47 specially prepared figures consisting of electron micrographs at a magnification of 15,000 and also at 2,500, the latter to compare with light micrographs of the same order of magnification. Detailed descriptive text is provided in connection with these micrographs, as well as details concerning the methods for sample preparation, etching, replica production, and shadowing.

ELEKTRISCHE MASCHINEN. Volume 5, Stromwendermaschinen für ein- und mehrphasigen Wechselstrom Regelsätze. By R. Richter. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany, 1950. 642 pages, illustrations, diagrams, charts, tables, 9¼ by 6½ inches, linen, 49.50 D.M. This fifth volume of a series on electric machinery provides a detailed treatment of the analysis and design of commutator machines for single and polyphase a-c operation. Calculations, experimental procedures, and control methods are dealt with, with particular attention to control setups using an auxiliary machine for purposes of phase compensation, speed control, or power regulation.

FUNDAMENTALS OF ACOUSTICS. By L. E. Kinsler and A. R. Frey. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1950. 516 pages, diagrams, charts, tables, 8¾ by 5¾ inches, linen, $6.00. This book presents the fundamental principles underlying the generation, transmission, and reception of acoustic waves. The first nine chapters provide an analysis of the various types of vibration of solid bodies and of the propagation of sound waves through fluid media. The remaining seven chapters are concerned with a limited number of applications of acoustics. A knowledge of the fundamental principles of mechanics, electricity, and calculus, including partial derivatives, is assumed.

INTRODUCTION TO ELECTRONICS. By J. Yarwood. Chapman and Hall, Ltd., 37 Essex Street, London, W. C. 2, England, 1950. 329 pages, illustrations, diagrams, charts, tables, 8¾ by 5¾ inches, cloth, 28s. This book considers the theory and practice of electronics. Following introductory material, the diode and triode, basic associated circuits, amplifiers, and oscillators are discussed. Modulation, detection, and heterodyne techniques are considered. The remaining chapters deal with photoelectric tubes, electron optics, cathode-ray tubes, the electron microscope, and ultrahigh-frequency thermionic tubes.

MODERN AIR-CONDITIONING, HEATING AND VENTILATING. By W. H. Carrier, R. E. Cherne, and W. A. Grant. Second edition. Pitman Publishing Corporation, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 574 pages, illustrations, diagrams, charts, tables, 10¼ by 7 inches, linen, $10.00. Providing a comprehensive treatment of the whole field, this book applies existing theory to actual practice in the industry. The second edition contains new material in the chapters on estimating, oil-burner applications, panel heating, air cleaning and purification, cooling coils, central conditioning systems, and automatic control. The section on psychrometrics is entirely rewritten, and new data have been added on the subject of comfort. Special topics, such as the economics of heating and conditioning systems and the control of noise and vibration, are also dealt with.

(Les) MOTEURS ÉLECTRIQUES POUR TOUTES APPLICATIONS. By R. Langlois-Berthelot. Éditions-Eyrolles, 61 Boulevard Saint-Germain, Paris (5e), 1950. 264 pages, diagrams, tables, 9¾ by 6½ inches, paper, 980 Frs. The characteristics and operation of electric motors of all types are analyzed, covering both d-c and a-c practice. Particular attention is paid to specialized machines and combinations of electric machinery and to consideration of the electric motor as a unit in such a combination. Brief space is devoted to installation problems in connection with various classes of applications.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographics, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

NATIONAL ELECTRONICS CONFERENCE PROCEEDINGS, Volume V, Chicago, Illinois, September 26–28, 1949. National Electronics Conference, 852 East 83rd Street, Chicago 19, Ill., 1950. 581 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $4.00. Some 60 specialized papers are presented in this volume, broadly classified under the following headings: electronic instrumentation; computers; television; antennas; measurements; magnetic devices; research management; theory of communications; vacuum tubes; electromagnetics; supersonics; and audio-frequency. The authors are research and development men from both industrial and academic fields.

PRINCIPLES OF SCIENTIFIC RESEARCH. By P. Freedman. Public Affairs Press, 2153 Florida Avenue, Washington, D. C., 1950. 222 pages, diagrams, charts, tables, 8¼ by 5⅛ inches, cloth, $3.25. The history, philosophy, psychology, planning, organization, and usefully applicable techniques of scientific research are discussed for the benefit of those entering, or concerned with, this important field. Examples are given in the last few chapters of the proper approach to a research problem in order to achieve optimum results for a minimum of time and effort expended.

REGISTRIERINSTRUMENTE. By A. Palm. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany, 1950. 220 pages, illustrations, diagrams, charts, tables, 9½ by 6½ inches, fabrikoid, 19.50 D.M. This book is a survey of recording instruments used in science and industry. It covers instruments with typical or special properties and those of commercial importance. The first part is devoted to a general consideration of registering or tracing means, methods, and driving mechanisms. Mechanical, electrical, and optical methods of measurement are then discussed with at least one instrument of each type described. The uses of various instruments are also considered.

TELEVISION, Volume V, 1947–1948, 461 pages, TELEVISION, Volume VI, 1949–1950, 422 pages, Edited by A. N. Goldsmith and Associates. RCA Review, Radio Corporation of America, RCA Laboratories Division, Princeton, N. J., August 1950. Illustrations, diagrams, charts, maps, tables, 9¼ by 6 inches, linen, $2.50 per volume, plus $0.20 postage outside United States. The fifth and sixth volumes of this series cover the years 1947–1948 and 1949–June 1950. Like the previous volumes, they contain papers written by Radio Corporation of America authors which were published in various technical journals and magazines. Each volume is presented in six sections: pickup transmission, reception, color, ultrahigh frequency, and general. Some papers, because of space requirements, are presented in summary form only, whereas other papers are presented as previously published. In volume VI, as an appendix, some 506 technical papers on television and related subjects, written by Radio Corporation of America authors and published from 1929 to June 1950, are listed chronologically.

TELEVISION SERVICING, THEORY AND PRACTICE. By W. H. Buchsbaum. Prentice-Hall, New York, N. Y., 1950. 340 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $5.35. Part I of this practical manual covers the theory of television receivers, starting with the picture tube and progressing to the antenna. The installation practices outlined in Part II conform with the methods employed by a number of well-established service organizations. Part III is a trouble-shooting guide, arranged by symptoms.

ULTRAHIGH FREQUENCY ENGINEERING. By T. L. Martin, Jr. Prentice-Hall, New York, N. Y., 1950. 456 pages, illustrations, diagrams, charts, tables, 8½ by 5¾ inches, linen, $8.00. Intended for senior students majoring in electrical engineering or physics, this book contains a general study of the techniques associated with ultrahigh-frequency systems. It deals with the theory and technique of the component parts that make up complete systems, but not with the functioning of such systems as a whole. Six general areas covered are the generation and synchronization of special wave forms, the amplification of ultrahigh-frequency systems, ultrahigh-frequency transmission systems, circuit elements, oscillators, and the propagation of signals. Mathematics through calculus is assumed.

as well as introductory courses in electron tubes and circuits.

A.S.T.M. STANDARDS ON TEXTILE MATERIALS, prepared by A.S.T.M. Committee D-13; Specifications, Tolerances, Methods of Testing, Definitions and Terms, October, 1950. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 572 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $4.50. The 1950 edition of this compilation includes in their latest form 90 specifications, test methods, and tolerances developed by the A.S.T.M. Committee on Textile Materials. A wide range of subject matter is provided relating to asbestos, bast and leaf fibers, cotton, glass textiles, hosiery, rayon and silk, and wool. Appendices include the basic properties of fibers, a psychrometric table, a yarn number conversion table, and several proposed test methods and recommended practices.

CLASSICAL MECHANICS. By H. C. Corben and P. Stehle. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 388 pages, diagrams, tables, 8¾ by 5½ inches, cloth, $6.50. The underlying assumptions of classical mechanics are presented in a manner intended to smooth the transition to quantum and relativistic mechanics. It includes the following topics not usually covered in books on mechanics: the problem of central motion; the theory of real linear vector spaces as applied to problems of oscillations, and so forth; the transformation theory of dynamics; Hamiltonian mechanics; Poisson brackets; and so forth. Relativistic mechanics is applied to the motion of ions in high energy accelerators.

ELEKTRISCHE HEIZEINRICHTUNGEN FÜR INDUSTRIE UND GEWERBE. By W. Schulz. Third edition. W. Schulz Selbstverlag, Kurhessenstrasse 162, Frankfurt A. M.-Ginnheim, Germany, 1950. 163 pages, illustrations, diagrams, charts, tables, 8¼ by 6 inches, paper, 6.40 D.M. Electric heating equipment for a wide variety of industrial purposes is described briefly, covering a range from small resistance elements to large drying ovens. Condensed information on fundamentals, calculations, and control devices also is included.

ENCYCLOPEDIA ON CATHODE-RAY OSCILLOSCOPES AND THEIR USES. By J. F. Rider and S. D. Uslan. John F. Rider, Publisher, 480 Canal Street, New York 13, N. Y., 1950. 982 pages, illustrations, diagrams, charts, tables, 11 by 8½ inches, linen, $9.00. This book covers the theory and uses of all types of cathode-ray oscilloscopes and synchroscopes manufactured from 1940 to 1950. It is divided roughly into four categories: the first dealing with theory and operation; the second, with applications; the third, with commercial oscilloscopes and related equipment; and the last is a compilation of 1,600 complex wave form patterns. Three appendices on the characteristics of cathode-ray tubes, Radio Manufacturers Association cathode-ray bases, and photography and a bibliography complete the book.

INTRODUCTION TO ELECTRON OPTICS. By V. E. Cosslett. Second edition. Oxford University Press, New York, N. Y.; and Clarendon Press, Oxford, England, 1950. 293 pages, illustrations, diagrams, charts, tables, 9½ by 6 inches, cloth, $6.00. This book provides a connected treatment of the production, propagation, and focusing of electron and ion beams. Its main emphasis is on the theory of electron lenses and their application in cathode-ray tubes and electron microscopes. Attention also is paid to other devices employing electron beams in radio and atomic physics. In the second edition a set of numerical examples is added to illustrate the theoretical work of the first five chapters. New material is collected in a series of notes at the end of the book.

OPERATIONAL CALCULUS BASED ON THE TWO-SIDED LAPLACE INTEGRAL. By B. Van der Pol and H. Bremmer. Cambridge University Press, American Branch, New York, N. Y., 1950. 415 pages, diagrams, charts, tables, 10 by 6¼ inches, linen, $10.00. Written for engineers and mathematicians, this book applies operational calculus in its modern form to mathematics, physics, and technical problems. It provides the basic principles, ideas, and theorems as well as many worked-out problems. Its purely mathematical treatment is more advanced than is usually found in books devoted to practical applications. The subject is treated by means of the bilateral or 2-sided Laplace integral rather than by the usual 1-sided Laplace integral. Rules, relations, and the various kinds of functions treated are presented in condensed form in an appendix.

PHYSICS, FUNDAMENTAL PRINCIPLES FOR STUDENTS OF SCIENCE AND ENGINEERING. 2 Volumes. By G. Shortley and D. Williams. Prentice-Hall, New York, N. Y., 1950. 1,271 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, Volume 1, $6.00; Volume 2, $7.35. Written as a text for sophomore engineering students, this 2-volume set provides a rigorous introductory treatment of the fundamental principles of physics. Mechanics and heat are considered in Volume I, and sound, light, electricity, magnetism, and modern physics in Volume II. Prerequisites are courses in chemistry and high-school physics and mathematics. A corequisite course in calculus also is assumed. The gravitational British-Engineering system and the absolute meter-kilogram-second system of units are used.

PRINCIPLES OF ELECTROMAGNETISM. By E. B. Moullin. Second edition. Oxford University Press, New York, N. Y.; Clarendon Press, Oxford, England, 1950. 311 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6.00. Written to provide a basic text for the author's teaching work, this book develops the subject as an immediate preliminary to subsequent study of electric machinery and communications methods. The subject matter is divided into the following major sections: elements of magnetism; second law of electrodynamics; iron in a magnetic field; and two groups of special electromagnetic equations. The new edition has an appendix enlarging on the skin effect of alternating currents.

PRODUCTION PLANNING AND CONTROL. By T. M. Landy. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 436 pages, illustrations, diagrams, charts, tables, 9¼ by 6¼ inches, linen, $5.50. Part I of this text deals with the problem of installing and operating a modern production planning and control system. Part II, the largest section, is a declaration of the principles and laws governing the subject, as well as a detailed analysis of the various functions. In Part III, supplementary but equally important functions are analyzed and illustrated with case studies. An appendix contains a list of abbreviations and symbols.

SIMILITUDE IN ENGINEERING. By G. Murphy. Ronald Press Company, New York, N. Y., 1950. 302 pages, diagrams, charts, tables, 9¼ by 6 inches, linen, $7.00. Written on the graduate-engineering level, this book is an organized presentation of the problems of model design and the interpretation of model tests. In the first part, the concepts and techniques of dimensional analysis are developed and utilized to develop the principles of design of models. In the second, a rational approach to the design of distorted models and results obtained from them are presented. The third and last is devoted to a study of analogies from the standpoint of model-prototype relationships.

WORLD GEOGRAPHY OF PETROLEUM (American Geographical Society Special Publication Number 31). Edited by W. E. Pratt and D. Good, published for the American Geographical Society by Princeton University Press, Princeton, New Jersey, 1950. 464 pages, illustrations, diagrams, charts, maps, tables, 10 by 6¾ inches, linen, $7.50. Based on information provided by a group of expert petroleum geologists and administrators, this book is a comprehensive discussion of the world oil situation. Part I is devoted to the discovery of oil-bearing areas. Part II describes the organization of the petroleum industry including development, production, storage, transportation, refining, and distribution. The main section of the book, Part III, considers all the great productive regions with the problems induced by their geology, topography, climate, vegetation, accessibility, population, culture, and industrial development. In Part IV the central theme is the geography of petroleum use. Fifty specially prepared maps, 11 diagrams, and 98 photographs are included to supplement the text.

PAMPHLETS

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

International Electrotechnical Vocabulary. This 1950 reprint contains nearly 2,000 scientific and technical terms, divided into 14 groups and some 100 sections. Complete definitions are given in French and English with the corresponding titles additionally listed in German, Italian, Spanish, and Esperanto. Available from the American Standards Association, 70 East 45th Street, New York 17, N. Y., at $4.50 per copy.

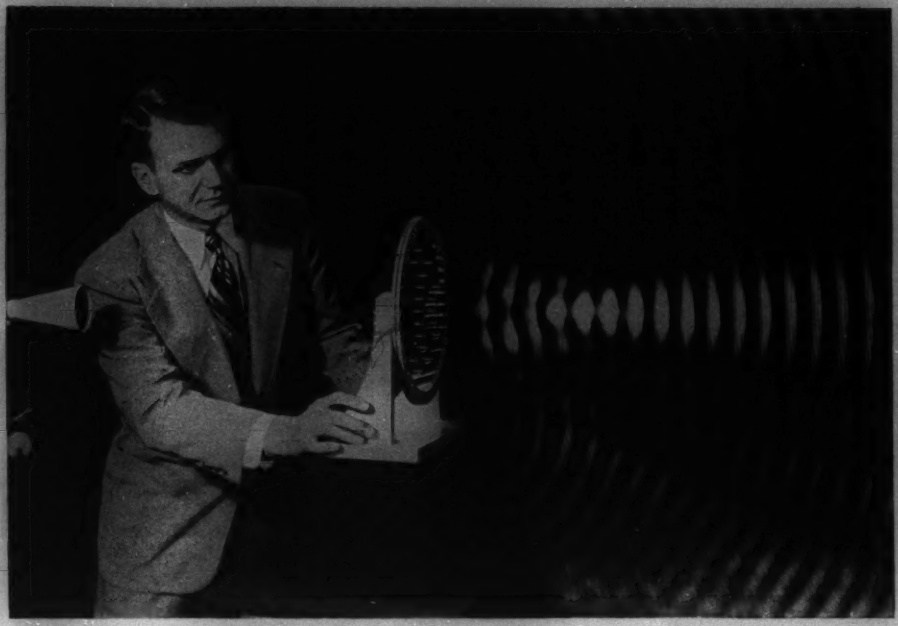
Related Instruction—A Key to Apprentice Training in Construction. Impending manpower demands make imperative assurance of a continuing supply of skilled workers for the construction industry. The responsibilities of interested groups in education, industry, labor, and government are discussed. Particularly emphasized is the role of vocational education in the related technical and supplemental instruction of apprentices. Available at 10 cents a copy from the Chamber of Commerce, Construction and Civic Development Department, Washington 6, D. C.

Research Is Learning. A comprehensive definition of the role of research in engineering education, compiled by representatives of 83 engineering schools. Also included are 12 brief summaries of universities' research activities which are designed to provide specific examples of the more general statements. Illustrated. Copies are available without cost on request to the Secretary of the Engineering College Research Council, Room 7-204, 77 Massachusetts Avenue, Cambridge 39, Mass.

Report on Standard Samples for Spectrochemical Analysis. Compilation of types and sources of standards for the information of analysts. There are listed in the form of extensive tables and data available standard samples on: iron and steel; aluminum and its alloys; magnesium and its alloys; zinc, lead, and tin alloys; and copper alloys. 36 pages. Available from American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at $1.25 per copy.

Bibliography of Technical Reports. A review of research in the incandescent brazing of copper bus bars is featured. Also included are items on the deterioration of cast-iron pipe; offshore petroleum operations; pectin in dehydrated foods; constant-pressure combustion; structural guides for the development of synthetic lubricants; standing-wave detectors; moisture absorption of tropical woods; and rescue and survival equipment. There are 259 technical reports from federal, foreign, and other reports. Available at 50 cents a copy from the United States Department of Commerce, Washington, D. C.

Supplement—Steam-Electric Plant Construction Cost and Annual Production Expenses—1937–1947. Presents cost data for 243 plants located in 40 states. Individual data sheets on each of the plants lists information on installed generating capacity, peak demand, cost of plant, production expenses, and quantity and cost of fuels used. The supplement presents data on 26 new plants not included in either the original 1938–47 publication or in the 1948 supplement. The supplement may be obtained for 50 cents from the Publications Sections, Federal Power Commission, Washington 25, D. C.



WAVE MAKING

–for better telephone service

Waves from the sound source at left are focused by the lens at center. In front of the lens, a moving arm (not shown) scans the wave field with a tiny microphone and neon lamp. The microphone picks up sound energy and sends it through amplifiers to the lamp. The lamp glows brightly where sound level is high, dims where it is low. This new technique pictures accurately the focusing effect of the lens. Similar lenses efficiently focus microwaves in radio relay transmission.

At Bell Telephone Laboratories, radio scientists devised their latest microwave lens by copying the molecular action of optical lenses in focusing light. The result was a radically new type of lens – the array of metal strips shown in the illustration. Giant metal strip lenses are used in the new microwave link for telephone and television between New York and Chicago.

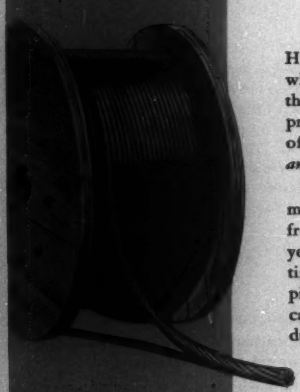
The scientists went on to discover that the very same type of lens could also focus sound . . . thus help, too, in the study of sound radiation . . . another field of great importance to your telephone system.

The study of the basic laws of waves and vibrations is just another example of research which turns into practical telephone equipment at Bell Telephone Laboratories . . . helping to bring you high value for your telephone dollar.

BELL TELEPHONE LABORATORIES

• WORKING CONTINUALLY TO KEEP YOUR TELEPHONE SERVICE ONE OF TODAY'S GREATEST VALUES

(Photo courtesy Knoxville Power Co.)



33 Years at hard labor . . .

High in the Smoky Mountains whipped by wind, rain, and sleet, this 5,010-foot Alcoa ACSR span proves the combined advantages of ACSR—*strength, light weight and economy.*

Installed in 1918, this almost mile-long span has given trouble-free service and is good for many years more . . . long-standing testimony to the success of Alcoa's pioneer ACSR work in sag tension calculations, vibration and conductor fatigue problems.

"What's in it for you" can be found in the records of Alcoa's aluminum experience built up over 63 years. This vast amount of shirt-sleeve, working knowledge about the design, manufacture and installation of conductors can help you solve your transmission line problems.

Although the rearmament program prevents unrestricted use of aluminum, we are ready to help you with the planning required for power transmission projects.

TECHNICAL HELP—NO OBLIGATION

Write for help, advice or technical literature. Address: ALUMINUM COMPANY OF AMERICA, 2102B Gulf Bldg., Pittsburgh 19, Pennsylvania.

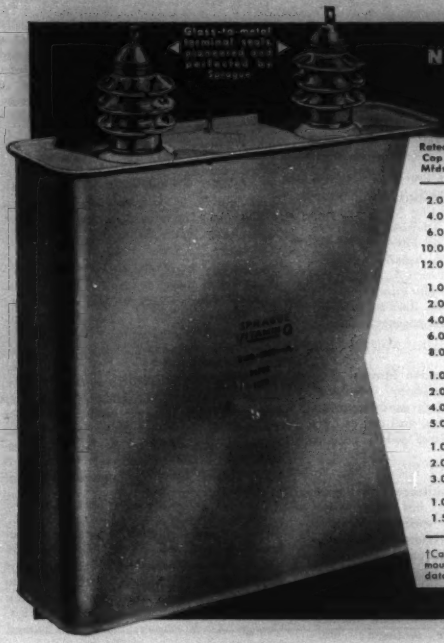
ALCOA

ALCOA FIRST IN ALUMINUM, FIRST IN **A·C·S·R**

Aluminum Cable Steel Reinforced

SMALLER, LIGHTER, LESS EXPENSIVE

HIGH VOLTAGE D-C CAPACITORS



NOTE THE SIZES AND RATINGS!

Standard Vitamin Q Capacitors. Many special sizes and ratings also available.

Rated Cap. Mfds.	D-C† Rated Voltage	DIMENSIONS Width	Depth	Can Height	Terminal Height	Cat. No.
2.0	8000	8⅛	4⅛	6	2¼	25P51
4.0	8000	8⅛	4⅛	9¼	2¼	25P52
6.0	8000	8⅛	4⅛	13	2¼	25P53
10.0	8000	13½	4¼	13⅛	2¼	25P54
12.0	8000	13½	5¼	12¼	2¼	25P55
1.0	10000	8⅛	4⅛	5½	3 11/16	25P56
2.0	10000	8⅛	4⅛	8½	3 11/16	25P57
4.0	10000	13½	4¼	9¼	3 11/16	25P58
6.0	10000	13½	4¼	13⅛	3 11/16	25P59
8.0	10000	13½	5¼	12⅞	3 11/16	25P60
1.0	12500	8⅛	4⅛	7½	3 11/16	25P61
2.0	12500	8⅛	4⅛	12¼	3 11/16	25P62
4.0	12500	13½	5¼	11½	3 11/16	25P63
5.0	12500	13½	5¼	13¾	3 11/16	25P64
1.0	16000	8⅛	4⅛	10½	4 11/16	25P65
2.0	16000	13½	4¼	12¼	4 11/16	25P66
3.0	16000	13½	5¼	13¾	4 11/16	25P67
1.0	20000	13½	4¼	11	4 11/16	25P68
1.5	20000	13½	5¼	12¼	4 11/16	25P69

†Capacitors with voltage ratings above 10 KV are recommended for upright mounting only. For mounting in other positions, please supply complete application data for recommendation by Sprague engineers.

USE an ordinary capacitor rated for 40°C. operation on a high-voltage d-c filtering circuit and chances are the higher temperatures encountered will necessitate a serious de-rating. In other words, you will have to buy a larger, heavier and costlier capacitor than you actually need.

Standard Sprague high-voltage capacitors impregnated with Vitamin Q, however, are rated conservatively for operation at 85°C. *They require no de-rating up to this temperature.* Special units can be supplied for continuous use up to 105°C.

These capacitors are consistently superior in their ability to maintain a high degree of capacitance-temperature stability. Power factor is outstandingly low over a wide temperature range; d-c insulation resistance is notably high; and a-c ripple voltage at audio frequencies falls well within permissible limits. Equally important, Vitamin Q impregnated capacitors have a high safety factor at all temperatures, thus assuring long life.

Write for Sprague Engineering Bulletin 203.

SPRAGUE VITAMIN Q* CAPACITORS

*Reg. U.S. Pat. Off.

SPRAGUE ELECTRIC COMPANY • NORTH ADAMS, MASS.

tested ways to protect your lines and equipment

TRAVELING WAVES ON TRANSMISSION SYSTEMS

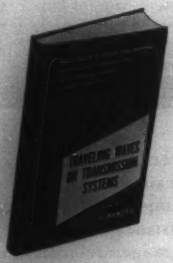
Second Edition

By L. V. BEWLEY, *Lehigh University*

Reduces Complex Theory to Practical Engineering Basis

In compact and usable form—the modern theories of transient surge phenomena, including changes in theory since 1930. These theories reduce the design of lightning-proof transmission lines to a routine procedure. They provide a basis for the most economical choice of protective features required for any desired degree of operating reliability.

new in the Second Edition:



A chapter on the practical design of protective systems

Data on attenuation and distortion of waves

Information on lightning

Theory of the counterpoise

A revised approach to switching surges and recovery voltages of circuit breakers

Multivelocity wave theory treated in detail

Enlarged by over half to include other significant developments in the field

270 illustrations designed to simplify methods of attack

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On 10 days' approval, send Bewley's *Traveling Waves On Transmission Systems.* I will remit $12.00 plus postage or return book postpaid. (Offer not valid outside U. S.)

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INDUSTRIAL NOTES ....

Standard Coil Products Company Acquires Kollsman Division. Standard Coil Products Company, Inc., of Los Angeles, Calif., and Chicago, Ill., has purchased from the Square D Company the latter's Kollsman Division, located in Elmhurst, L. I., N. Y. The Kollsman Division, which manufactures aircraft instruments, will continue to operate with the same personnel in the same plants. Victor E. Carbonara, who has headed this division for over ten years, will be its President. The purchase price was stated to be around $5,000,000.

RCA Elections. Walter A. Buck, a former Rear Admiral in the United States Navy, and since 1949 Operating Vice-President of the RCA Victor Division, has been elected to the Board of Directors of the Radio Corporation of America (RCA). Mr. Buck succeeds Edward J. Nally, who has retired. RCA has also announced the appointment of David S. Rau as Assistant Vice-President and chief engineer of RCA Communications, Inc.

Measurements Corporation Moves. The Measurements Corporation, Boonton, N. J., has moved all their manufacturing departments, laboratories, and offices into their new Intervale Road plant, also in Boonton.

Sylvania Electric Appointments. Sylvania Electric Products, Inc., has made three new appointments in their Radio and Television Division: Howard Riordan, formerly Vice-President and controller of the Colonial Radio Corporation (once a subsidiary of Sylvania), has been appointed general manufacturing manager; Bernard O. Holsinger has been named assistant general sales manager; and Hulbert C. Tittle has been made assistant chief engineer.

Rockbestos Products Promotions. Two major appointments were announced by the Rockbestos Products Corporation: Charles A. Berlepsch was named to the newly created post of Director of Purchases, and Raymond B. Miniter was named as purchasing agent.

Minneapolis-Honeywell Buys Thomas M. Royal Plant; Appointments. The Brown Instrument Division of the Minneapolis-Honeywell Regulator Company is expanding its industrial production and operating facilities in Philadelphia by the purchase of the Thomas M. Royal plant and about 60,000 square feet of undeveloped property in addition and adjacent to the new site. The Minneapolis-Honeywell Regulator Company also has announced the following appointments: Eldon E. Fox has been named advertising manager; R. M. Locke, assistant sales manager, wholesale division; J. C. Dorsey, sales manager, manufacturers' division, mid-Atlantic region, Philadelphia; H. S. Gray, sales manager, wholesale division, midwest region, Chicago; W. E. Dobie, sales manager, wholesale division, eastern region, New York City; and R. G. Hayes, sales manager, wholesale division, mid-Atlantic region, Philadelphia.

Philco Subsidiary to Build New Plant in Maryland. The Lansdale Tube Company, Lansdale, Pa., a subsidiary of the Philco Corporation, has purchased a site at Frederick, Md., for a new electronic tube plant, which is scheduled to be in operation before the end of 1951.

I-T-E Names Arizona Representative. The I-T-E Circuit Breaker Company, Philadelphia, Pa., has named the Central Station Engineering Company, Tucson, Ariz., as its Arizona representative.

Thompson Products Enters Electronics Field. Thompson Products, Inc., manufacturers of parts for the automotive and aircraft industries, is entering the electronics field via an exclusive license agreement with Designers for Industry, Inc. By this agreement, the company has taken over the development, manufacture, sales, and service of coaxial switches. An electronics division is being established at the Thompson Cleveland main plant under the direction of Len W. Reeves, Vice-President. The engineering program is being guided by A. L. Pomeroy, Director of Staff Development.

Allis-Chalmers Forms Chicago Warehouse Sales Unit. The Allis-Chalmers Manufacturing Company has set up a new section in their Chicago district office to handle the sale of small apparatus including motors, controls, drives, and pumps. George A. Wampler has been named manager.

G-E Appointments. The General Electric Company has announced the appointments of Leon C. Swager as wage administrator for the company's Fort Wayne works; Robert C. Walton as assistant to the manager of marketing of the General Electric Appliance and Merchandise Department; and J. P. Evans as assistant manager of appliance sales in the company's North Central District.

H. L. Cramer Appointed to New Westinghouse Sales Post. The creation of a new sales department—the Agency and Construction Department—and appointment of Harold L. Cramer as its manager, has been announced by the Westinghouse Electric Corporation.

National Carbon Plans Major Electrode Plant Expansion. The National Carbon Division of the Union Carbide and Carbon Corporation has announced plans for a further major addition to its present carbon electrode plant at Columbia,

(*Continued on page 22A*)

BIDDLE *Instrument News*

- ELECTRICAL TESTING INSTRUMENTS
- SPEED MEASURING INSTRUMENTS
- LABORATORY & SCIENTIFIC EQUIPMENT

NUMBER 5 OF A SERIES

JAMES G. BIDDLE CO., 1316 ARCH ST., PHILADELPHIA 7, PA.

CERTAINTY IN CIRCUIT TESTING WITH DIRECT INDICATING, TRUE OHMMETER

Midget Megger® Makes Many Friends

From a chief electrician of a New England fishery . . . from the Mechanical Department of a railroad . . . from users in many different industries . . . we receive letters of enthusiasm for the Midget "Megger" Circuit Testing Ohmmeter. Reports show these instruments last several decades and one user claims, "It has paid for itself 25 times or more."

This little instrument is not merely a voltmeter calibrated in ohms; it's a true ohmmeter, using any make of flat type, 3-cell flashlight battery, but operating independently of the exact battery voltage.

Push-button spring terminals for quick connections. Your choice of push-button battery switch on instrument or testing spike. Ohm scales available for ranges from .1 ohm to 200,000 ohms. Each scale has two ranges.

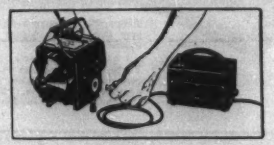
An "A-1" Trouble Shooter

For testing coils, resistors, contacts, windings, circuits, relays, etc., and even insulation resistance up to 50 and 200,000 ohms.

New Bulletin mailed on request. Please ask for 1495-EE.

NOW, A MEGGER® THAT OPERATES *TWO WAYS*

1. By hand



2. By Plug-in Rectifier

Here is the instrument that gives you the greatest facility of insulation resistance testing . . . a regular hand-crank Megger instrument with a separate plug-in rectifier. Use the hand-crank, constant voltage generator for working from place to place around the plant. Use the plug-in rectifier for the repetitive "bench" work type of tests . . . also for the long, time-resistance tests. Rectifier works on any 115 v. 60-cycle outlet. Hand-crank generator is automatically disconnected when you hook up the rectifier.

Two important accessory features can be incorporated in the Dual-Operated set by means of a Selector Switch: (1) an Ohm Scale from 0 to 10,000 to augment the regular megohm scale and (2) a Discharge Switch to dissipate D-C charge immediately preceding or following a test.

If you need a Megger tester only for repetitive, production acceptance tests, or for time-resistance testing, we furnish the Rectifier-Operated Meg type Megger Insulation Tester with built-in transformer and rectifier. No hand-crank; just plug into 115 v. 60 cycles.

For a detailed description, write for Bulletin 21-46-EE.

BIDDLE IMPULSE CABLE FAULT LOCATOR WINS APPROVAL IN A VARIETY OF INDUSTRIES

A large automobile manufacturing plant, several major power and light companies, a traction company, a well-known oil company, have recently bought Biddle Impulse Cable Fault Locators and D-C Proof Testers. The

broad diversity indicates, in a measure, the wide usefulness and economic advantages of this instrument. A mobile unit that recently toured the country brought much acclaim for the equipment wherever it was demonstrated.

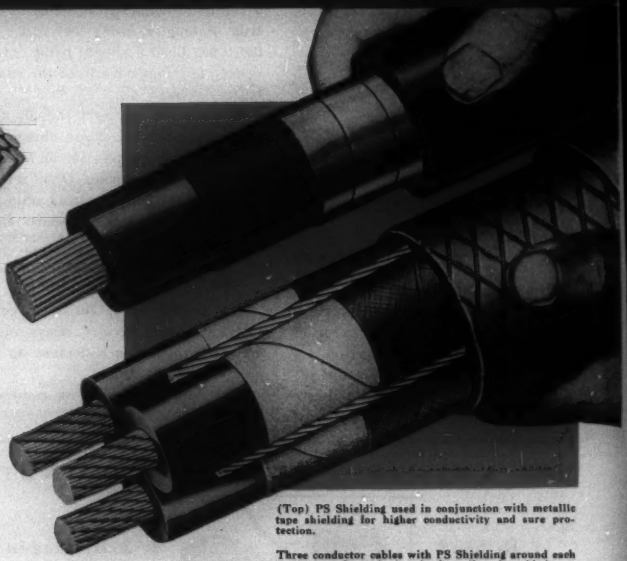
Your correspondence is invited . . . For a detailed description, ask for Bulletin 65-EE.

We are constantly publishing new technical bulletins on Biddle Instruments. A complete list of our latest bulletins will be mailed you on request, so that you may check it to bring your files up-to-date.

What type of power cable?

Unshielded? Metallic Shielded?

PS Shielding used directly over the conductor and also around the insulation.



(Top) PS Shielding used in conjunction with metallic tape shielding for higher conductivity and sure protection.

Three conductor cables with PS Shielding around each conductor. Ground wires in the valleys for added conductivity and strength. PS Shielding tapes coated with aluminum are used to identify a conducting tape.

Forms of PS Shielding

1. A thin coating or "skin" of conducting rubber.
2. A substantial sheath combining conductivity and mechanical protection.
3. A fibrous tape coated with conducting rubber.
4. A conducting paint or cement.

Who developed PS Shielding?

Research engineers at American Steel & Wire Company pioneered in this field many years ago. Since then, numerous other companies have been licensed to use conducting rubber tapes in electrical cable construction.

shall I use—
Non-Metallic PS Shielding?

● This subject has frequently come up for deliberation among outstanding power transmission engineers. They have thrown considerable light on the question and any buyer of cable will want to weigh the advantages and disadvantages of each type.

Unshielded insulated cable can generally be used up to 5000 volts without much trouble from corona and ozone formation.

Metallic Shielding in the form of metal tapes, wire braids and wire servings has been used with success under favorable conditions for cables 5000 volts and up. However, lack of flexibility may cause serious trouble. With expansion and contraction, bending and straightening, the metal shield tends to separate slightly from the insulation forming air gaps. Each air gap is a potential danger point causing spark discharges with corona and ozone formation—highly deteriorating to an organic insulating material.

Non-metallic PS Shielding with conducting tapes for cables 5000 volts and up, eliminates many of the weaknesses of metallic shielding. PS Shielding consists of a fibrous tape coated with a conducting rubber. It stays flexible—remains in intimate contact with the conductor or insulation. No air gaps can form and destructive sparkling is prevented. Corona is definitely eliminated—and so is ozone.

Type PS Shielding may be used alone, in combination with ground wires, or as a supplement to metallic shielding. We are now able to offer a conducting rubber compound that will provide improved shielding for any type of high-voltage cable.

Write for our booklet, "Type PS Semi-Conducting Shielding" which gives complete information.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA STEEL COMPANY, SAN FRANCISCO
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM, SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

American Electrical Wire and Cable

UNITED STATES STEEL

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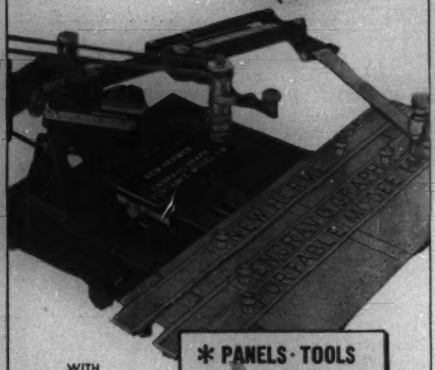

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Designed by Vickers to help students obtain a wider knowledge of the characteristics and applications of high-performance self-saturating magnetic amplifiers.

- Permits study of all three basic single phase self-saturating circuits.
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- Gives d-c or a-c output, uses d-c or a-c control power.

INCLUDED WITH EACH UNIT—Magnetic Amplifier Laboratory Manuals and Magnetic Amplifier Design Handbooks.

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PORCELAIN INSULATORS THAT

YOUR NEEDS

This insulator half ring is an excellent example of Universal's ability to design and manufacture ceramic insulators to fit specific needs. In addition, it provides every quality of fine porcelain — uniform density of body, high dielectric factor, resistance to temperature extremes, physical shock, fumes, moisture, corrosion, smoke and acids. For insulators to fit your requirements, consult with Universal. An experienced engineer will be glad to assist you.

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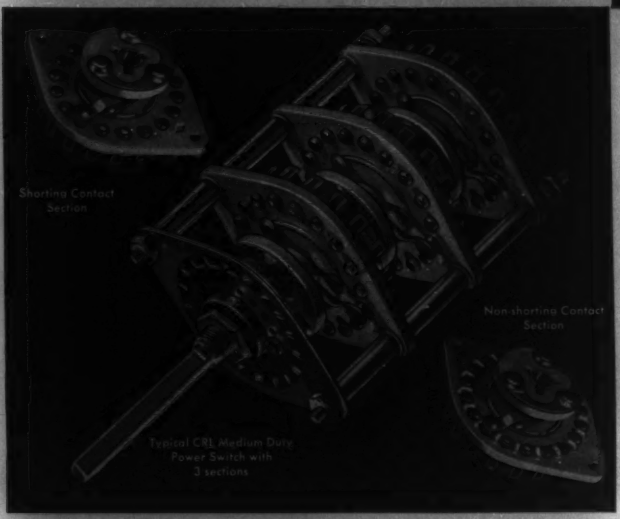
1560 EAST FIRST STREET U SANDUSKY, OHIO
TRADE MARK

CENTRALAB MAKES

CUSTOM BUILT MEDIUM-DUTY POWER SWITCHES

CHOOSE FROM THE NEW CENTRALAB LINE OF ELECTRONIC COMPONENT PARTS



ONLY CENTRALAB MEDIUM-DUTY POWER SWITCHES GIVE YOU WIDE CHOICE OF STANDARD OR CUSTOM COMBINATIONS

STANDARD MEDIUM DUTY SWITCH SIZES

Part No. Shorting	Part No. Non-Shorting	Total Poles	Positions	Total Sections	Poles per Section
JV9000	JV9001	1	2-17	1	1
JV9002	JV9003	3	2- 5	1	3
JV9004	JV9005	2	2-17	2	1
JV9006	JV9007	6	2- 5	2	3
JV9008	JV9009	3	2-17	3	1
JV9010	JV9011	9	2- 5	3	3
JV9012	JV9013	4	2-17	4	1
JV9014	JV9015	12	2- 5	4	3
JV9016	JV9017	5	2-17	5	1
JV9018	JV9019	15	2- 5	5	3
JV9020	JV9021	6	2-17	6	1

Furnished with adjustable stop to limit rotation to desired number of positions

Centralab's Medium-Duty Power Switches are made to meet your individual needs — 1, 2 or 3 poles — 18 contacts per section — up to 20 sections per shaft. Contacts and collector rings are of coin silver, mounted on Grade L5 Steatite . . . compounded and produced right in our own plant.

Switches are designed for R.F. or 7½ amp., 110-115 V. application. The combination of rugged construction — coin silver contacts plus the high insulation resistance of Grade L5 Steatite means long-term, trouble free performance.

For top-performing, medium-duty power switches, in standard or custom models, ask about Centralab's famous "torture-tested" switch line. Our engineers will be glad to assist you.

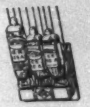
Centralab CRL
Division of GLOBE-UNION INC. • Milwaukee

CERAMIC CAPACITORS

Centralab Ceramic capacitors offer every value you need for modern electronic equipment. You can get tiny disc-types (smaller than a dime) for by-pass or coupling applications. You can get temperature compensating or by-pass coupling tubulars . . . and you can get true high voltage (10, 20, 30 KV) ceramics that are the accepted standard of the TV industry.

PRINTED ELECTRONIC CIRCUITS

P.E.C.'s are a startling development for saving soldered connections, space, weight and man-power. Used where small size is prime essential.



VARIABLE RESISTORS

Centralab makes a complete line of variable resistors (controls) for nearly all low-wattage requirements.

SPECIAL EQUIPMENT

Centralab offers wide variety in special capacitors, tubular trimmers, switches, Steatite and other ceramic components. Write direct stating your problem.

CENTRALAB Div. of Globe-Union Inc.
927 East Keefe Avenue
Milwaukee 1, Wisconsin

FREE
Mail this coupon for your copy of Centralab Switch Catalog No. 722. Check below for other literature wanted.

.....Hi-Voltage Ceramic Capacitors
.....Disc-Type Ceramic Capacitors
.....Tubular Ceramic Capacitors
.....Printed Electronic Circuits
.....Variable Resistors

Name.....
Company Name.....
Address.....
City.....Zone.....State.....

WHAT ARE THE TWO MOST IMPORTANT "INGREDIENTS" OF A MOTOR BRUSH?

Most small motor brushes are made from the same basic materials, on the same type of equipment, under much the same conditions. What then, makes one line of brushes so outstandingly superior to another for a given application?

Here at Stackpole, we're convinced there are two chief factors involved: (1) Laboratory Engineering by brush experts who produce a brush formula for the specific product involved under actual operating conditions and, (2) Statistical Quality Control that covers brush processing from the base materials through every step of manufacture. Characteristics are carefully controlled, maximum uniformity assured.

Long experience proves that, backed by these two basic Stackpole ingredients, almost any small motor brush performance can be materially improved.

● *Stackpole brushes are sold only to makers of original equipment* ●

STACKPOLE

Write today for your copy of this helpful 44-page Brush Users' Guide

STACKPOLE CARBON CO.
ST. MARYS, PA.

(*Continued from page 16A*)

Tenn. Production from the new facilities is expected to begin by the middle part of 1951, and when completed by early 1952 will add many million pounds of graphite production annually, as well as materially increase the production of carbon electrodes. As a further part of their program to supply carbon electrodes to meet the growing demand for electrical steel, improvements are also being made at the corporation's electrode plants at Clarksburg, W. Va., and Niagara Falls, N. Y.

Philco Appointments. Frederick J. Willard has been appointed Vice-President of sales, F. Leroy Sherman Vice-President of foreign operations, and Radcliffe L. Romeyn has been made Vice-President and executive assistant to the President of the Philco International Corporation. The Philco Corporation has also announced the appointment of Bert Cole as district sales representative for the New York—Newark area.

NEW PRODUCTS • •

Static Magnetic Memory. Developed by the Harvard Computation Laboratory and manufactured by the Alden Products Company, 117 North Main Street, Brockton, Mass., the Static Magnetic Memory is a new device for recording and storing information in digital calculating machinery. Based upon the discovery of a ferromagnetic alloy having a fairly rectangular hysteresis loop of low coercive force, the Static Magnetic Memory operates essentially as a magnetic trigger pair which requires no vacuum tubes to maintain position. Permanent information storage of this device is comparable to magnetic drum storage, but independent of mechanical movement. A variable information handling rate ranges from zero to 30,000 cycles per second with probable increases in the future limit, and pulse information storage without power. Any further information may be obtained from the Alden Products Company.

Copyflex. The Charles Bruning Company has developed a new type of office copying machine which needs no inks, tray developing, special lighting, stencils, or negatives. Called the "BW Copyflex," this machine uses the BW Diazo process, which is based on paper coated with an analine dye. Within the machine this dye coating is bleached by actinic light rays, except where the record or document to be copied has markings, such as typing, printing, or line drawing. These markings prevent light from bleaching the dye, and a sharp, clean, black line is formed, reproducing exactly the markings on the original copy. If the original document is marked on both sides or is on opaque stock, the machine copies it onto BW reflex film and the film then is used to make as many copies as are desired. Both sides of an

(*Continued on page 30A*)

No matter how unusual your generator may be . . .

we can build New-Born Power into it!

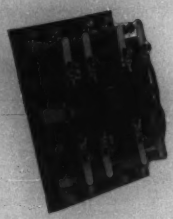
Peculiarities of design such as those in the turbo-alternator rotor above, photographed in our shop, hold no terrors for National Electric Coil engineers. In this case, removable tooth-sections allow the field coils to be hot-pressed and seasoned as a complete coil unit. Each finished coil is placed on the rotor core and the tooth-sections are inserted. National is prepared, by experience and equipment, to take advantage of every opportunity afforded by design and construction to give you maximum power and life. *Now* is the time to make sure your rotating electrical equipment is ready for the job which lies ahead. Write or wire (or cable Natcoil, Columbus).

NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION — DESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

Multi-Contact RELAYS for Specialized Controls



featuring — Mechanical locking, no latching. Single solenoid action with integral control contacts permitting circuit connections equivalent to a two-coil unit. Wiping and adjustable contacts for reliable service at milliamperes of load at low voltage or at full rating.

rated at — 10 and 25 amperes; AC to 550 volts; DC to 250 volts.

in three available combinations — 10 amperes to 12 poles normally open and 12 poles normally closed or any combination of normally open and normally closed poles. 550 volt AC maximum.

10 amperes to 6 poles normally open and 6 poles normally closed or any combination of normally open and normally closed poles. 250 volt DC maximum.

25 amperes to 6 poles normally open and 6 poles normally closed or any combination of normally open and normally closed poles. 250 volt DC 550 volt AC maximum.

Do you require a sturdy reliable RELAY to maintain circuit control regardless of momentary interruption in control line due either to low voltage or associated relay operating time? Do you need a RELAY to provide "memory" circuits or to permit preset control operations? Utilities have found them very useful in combination for AC service on contacts, DC operating coil. Control systems needed for many machine tools, industrial machines and furnaces will find such a RELAY in this special ASCO design. And when the AC hum of a magnetically-held relay would be a nuisance, this mechanically held ASCO RELAY would be ideal.

In writing for further information, write us fully about your requirements.

AUTOMATIC TRANSFER SWITCHES • REMOTE CONTROL SWITCHES • CONTACTORS • RELAYS

We also manufacture a complete line of Solenoid Operated Valves for Automatic and Remote Control of Liquids and Gases

ASCO Electro-Magnetic CONTROLS

Automatic Switch Co.

385-F Lakeside Avenue • Orange, New Jersey

RECOMMENDED PRACTICE FOR

Electric Installations on Shipboard

(MARINE RULES)

No. 45 AIEE Standards

"Recommended Practice for Electric Installations on Shipboard" (Marine Rules) is published as Section 45 of the AIEE Standards. The pamphlet contains 150 pages; price is $3.50 (50% discount to members of the AIEE on single copies).

Latest Edition December 1948

These Rules have been drawn up to serve as a guide for the equipment of merchant ships with electric apparatus for lighting, signaling, communication, power and propulsion for both alternating and direct current systems. They indicate what is considered good engineering practice with reference to safety of the personnel and of the ship itself, as well as reliability and durability of the electric apparatus.

American Institute of Electrical Engineers

33 West Thirty-Ninth Street, New York, 18

2-51

BUILT BY BETA

FOR A PROMINENT CABLE & WIRE MANUFACTURER*

PORTABLE HIGH VOLTAGE CABLE TESTER

Model 219 control cabinet (high voltage tank not shown)

0—135 KV DC, High voltage (+) or (—) to ground

100 MA available at 135 KV; 250 MA available below 100 KV

Ripple less than 1%

Stabilized output voltage ± 1% against line voltage and load current changes.

Adjustable rate of rise of voltage: ½ to 10 KV per second

Many other control and metering features. Entire unit on swivel casters.

BETA High Voltage Cable Tester

This high voltage cable tester was built to provide safe, reliable and convenient source of very high voltage DC for power cable testing. Multiple range meters, protected on all ranges, allow for accurate insulation resistance characteristic measurements over a very wide range of resistance values.

*name given upon request

SPECIALIZING IN HIGH VOLTAGE EQUIPMENT

The Beta Electric Corporation specializes in the design and construction of high voltage equipment like the cable tester described above. These units are built for the client's application, to the client's specifications. Beta also builds a standard line of high voltage power supplies up to 30 KV, portable projection oscilloscopes, and kilovoltmeters. Power supplies up to 500 KV DC can be supplied. Beta stresses good design and construction, which make for efficient equipment, ease of operation, low maintenance costs, fast delivery, and low prices.

Field Engineer Service

Beta field engineers throughout the country are at your service to discuss high voltage applications and equipment.

PHONE OR WRITE TODAY!

BETA ELECTRIC CORP.

333 E. 103 St., New York 29, N. Y.

Cables run COOLER...
in TRANSITE DUCTS

... reducing copper losses

... increasing current capacity

... prolonging insulation life

HERE'S HOW to reduce copper losses ... increase current carrying capacity ... and prolong insulation life—run your cables in Transite* Ducts.

Current carrying capacities can be increased in a typical duct bank as much as 5%, or I^2R losses can be reduced 11%, for cables located in Transite as compared with other ducts used for power circuits.

And, Transite Ducts assure permanent duct banks because Transite is incombustible; is immune to rust and rot; is unaffected by electrolysis; will not slag under action of an arc, and will retain its high original strength.

An unusually smooth bore assures no injury to cable sheath, either in natural movement under load, or when pulling-in cables. Long, lightweight lengths can be quickly and economically installed. In addition, a full line of fittings simplifies even the most complicated of installations.

For full information on Transite Ducts, write for Data Book DS-410. Johns-Manville, Box 290, New York 16, N. Y.

JM

*Reg. U. S. Pat. Off.

How Transite Ducts increase current carrying capacities

Type cable 3 cdr. 500 MCM Compack Sector, 15 KV (6th Edition AEIC Spec.)
No. of cables—3 (all loaded in one bank)
Daily Load Factor—75%
Earth Temp. ambient—20 C

	Transite	Other
Total Therm. Res. to Dielectric Loss (C watts/ft.)	5.66	6.17
Total Therm. Res. to Copper Loss (C watts/ft.)	4.44	4.95
Temp. Rise from Dielectric Loss (C)	1.9	2.1
Allowable Rise for Copper Loss (C)	59.1	58.9
Allowable Watts per ft. cable	4.44	3.96
Allowable Current—(Amps. per cdr.)	386.	365.
Allowable Current—(Relative %)	105.6	100.

Johns-Manville *Transite Ducts* **"KORDUCT"— for encasement in concrete**

"CONDUIT"— for use exposed and underground without encasement

MINIATURE RELAYS FOR AVIATION'S TOUGHEST JOBS

Multipole Types, Too!

In addition to the single-pole units illustrated, Struthers-Dunn produces these hermetically-sealed aviation relays in types up to 6 poles and having the same exacting characteristics.

These little hermetically-sealed d-c relays are specifically designed for aviation conditions involving high shock and vibration, elevated temperatures and high altitudes. A completely new magnet structure permits greatly reduced size with improved dependability. Three available types are for operation up to +85°C., +160°C. and +200°C. respectively, thus matching specific aviation service requirements. Write for S-D Data Bulletin 2410.

STRUTHERS-DUNN

5,348 RELAY TYPES

STRUTHERS-DUNN, INC., 150 N. 13th ST., PHILADELPHIA 7, PA.

BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI
CLEVELAND • DALLAS • DETROIT • KANSAS CITY • LOS ANGELES
MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PITTSBURGH
ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

Where the Requirements are Extreme...

Use SILVER GRAPHALLOY*

For extraordinary electrical performance

GRAPHALLOY
TRADE MARK REG. U. S. PAT. OFF.

THE SUPREME BRUSH AND CONTACT MATERIAL

IN BRUSHES

- **for high current density**
- **minimum wear**
- **low contact drop**
- **low electrical noise**
- **self-lubrication**

IN CONTACTS

- **for low resistance**
- **non-welding character**

*Graphalloy is a special silver-impregnated graphite

Accumulated design experience counts — call on us!

GRAPHITE METALLIZING CORPORATION

1053 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

ALLIS-CHALMERS

POLE-TYPE 5/8% STEP REGULATOR

Why Lose $4 per Customer per Year?

LOW VOLTAGE CAN COST YOU THAT OR MORE!

OPERATORS WHO LOOK at 105v or 110v as *"adequate"* for feeders are losing from $4 to $8 annual revenue for every customer. Now that most appliances are rated 120v instead of 110v, you can lose many thousands of dollars if you permit voltage to stay at a level that was once considered adequate. It costs money *not* to regulate voltage!

There are several ways to raise voltage and cut revenue losses. Regulators are a common method. But there's a big difference in regulators! For example, a regulator that holds a narrow 2 volt band can maintain average voltage 1 volt higher than a regulator holding a 4 volt band.

Band width is therefore the real way to judge a regulator. Allis-Chalmers pole type step regulator is the only pole type step regulator on the market today that holds a 2 volt band.

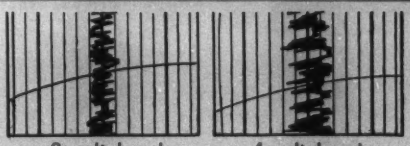
The band width advantage can be used in any one of these three ways:

1. You can use it to increase revenue.
2. You can use it to increase load-carrying capacity.
3. You can use it to extend feeder length.

Hundreds of these regulators are already in use. Find out what the narrow band width of Allis-Chalmers pole type step regulators can mean on your lines. Call your nearby Allis-Chalmers Sales Office for the complete story. A-3181

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

Judge a Regulator by the Band Width It Holds!

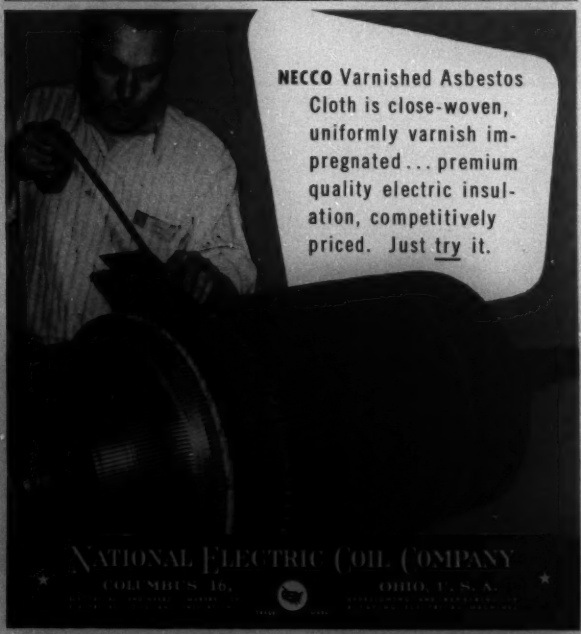


The Allis-Chalmers pole type regulator is the only pole type step regulator that can hold a narrow 2 volt band. Use the band width advantage of this regulator to hold higher average voltage. Get quicker return on dollars invested in regulation.

ALLIS-CHALMERS

Originators of 5/8% Step Regulation

ILSCO COPPER TUBE & PRODUCTS, INC.
5743 MARIEMONT AVE. CINCINNATI 27, OHIO


NECCO Varnished Asbestos Cloth is close-woven, uniformly varnish impregnated... premium quality electric insulation, competitively priced. Just try it.
NATIONAL ELECTRIC COIL COMPANY
COLUMBUS 16, OHIO, U.S.A.

AIEE POWER CONFERENCE

This publication (S-38) contains the 19 papers presented at the first AIEE Power Conference, sponsored by the AIEE Power Generation, Industrial Power Systems, and System Engineering Committees, held in April, 1950.

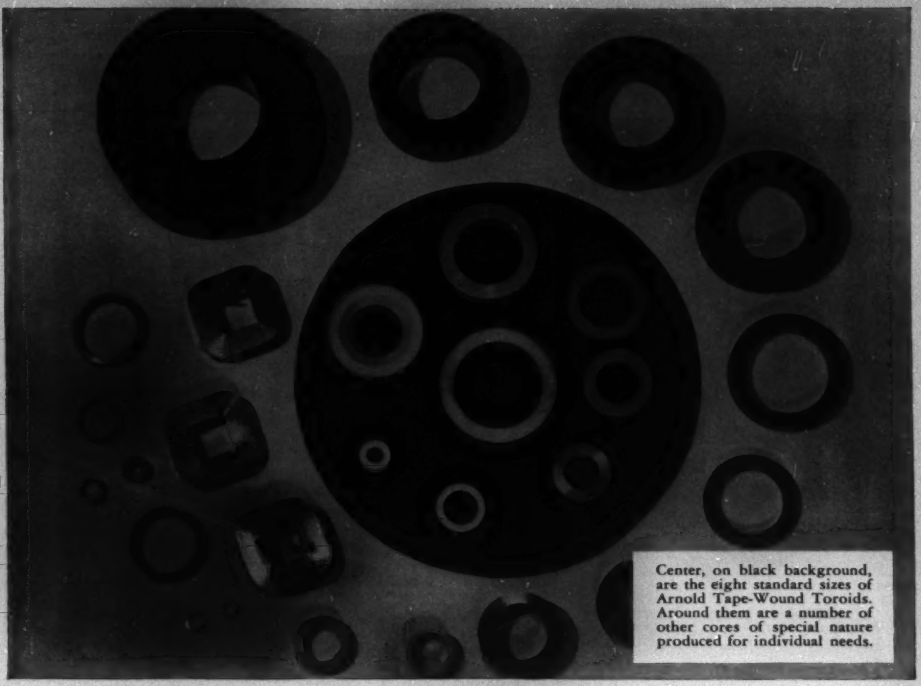
The 19 papers, some by well-known authorities in the power field, were grouped under two major classifications: power generation and industrial power systems. In the power generation sessions, two topics were considered — the planning problem and the operating problem.

More than half of the papers were devoted to industrial power systems. This particular session reviewed the technical progress that has been made during the last decade.

It is hoped that these papers and discussions will serve as a ready reference and as a comparison between present day and future practices. 235 pp. illustrated. Price: $3.00 ($2.50 to AIEE members).

Send orders for S-38 to:
Order Department
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street
New York 18, N. Y.

2-51



Center, on black background, are the eight standard sizes of Arnold Tape-Wound Toroids. Around them are a number of other cores of special nature produced for individual needs.

ARNOLD TAPE-WOUND TOROIDAL CORES

of DELTAMAX 4-79 MO-PERMALLOY SUPERMALLOY*

APPLICATIONS

MAGNETIC AMPLIFIERS
PULSE TRANSFORMERS
NON-LINEAR RETARD COILS and TRANSFORMERS
PEAKING STRIPS, and many other specialized applications.

RANGE OF SIZES

Arnold Tape-Wound Toroids are available in eight sizes of standard cores—all furnished encased in molded nylon containers, and ranging in size from ½" to 2½" I.D., ⅝" to 3" O.D., and ⅛" to ½" high.

RANGE OF TYPES

These standard core sizes are available in each of the three magnetic materials named, made from either .004", .002" or .001" tape, as required.

In addition to the standard toroids described at left, Arnold Tape-Wound Cores are available in special sizes manufactured to meet your requirements—toroidal, rectangular or square. Toroidal cores are supplied in protective cases.

**Manufactured under licensing arrangements with Western Electric Company.*

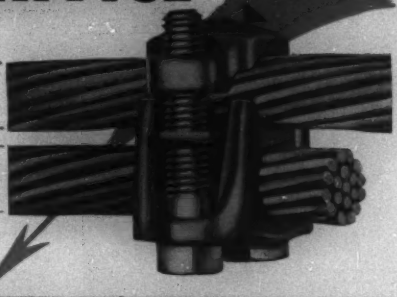
W&D 3182

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

ENGINEERED
FOR
UNINTERRUPTED
POWER
SERVICE



TYPES "K" AND "KR" CONNECTORS ARE • •

DESIGNED: With each component of a special alloy for high strength and to achieve a specific electrical and mechanical function.

DESIGNED: With flexing arch type clamping members to retain high pressure contacts on conductors during vibration and temperature changes.

DESIGNED: To transmit high pressure contacts from connector clamping members through each conductor strand to core wire.

DESIGNED: To limit high resistance oxide formations on connector contact and conductor interstrand contact surfaces.

DESIGNED: To eliminate connector failures resulting from heavy short circuit current surges passing through oxide contamination on connector and conductor interstrand contact surfaces.

DESIGNED: To withstand Mercurous Nitrate Specification ABW-124-1* which insures against seasonal and stress corrosion cracking failures.

DESIGNED: In two styles, "KR" with conductor spacing bar, "K" without. Both "K" and "KR" series include 7 sizes for conductors from #8 to 1000 MCM.

*Identical to ASTM B-154-45 Mercurous Nitrate Specification except ABW-124-1 specifies stressed components which is a more severe test.

Consult one of our nearest 19 representatives or contact our main office.

Write today for Bulletin K-175 on "K" and "KR" Distribution Connectors.

ANDERSON BRASS WORKS, Inc.
POST OFFICE DRAWER 2151
BIRMINGHAM, 1, ALABAMA

• POWER AND ALUMINUM POWER CONNECTORS, FITTINGS, AND BUS SUPPORTS
ALUMINUM SUSPENSION AND STRAIN CLAMPS

(*Continued from page 22A*)

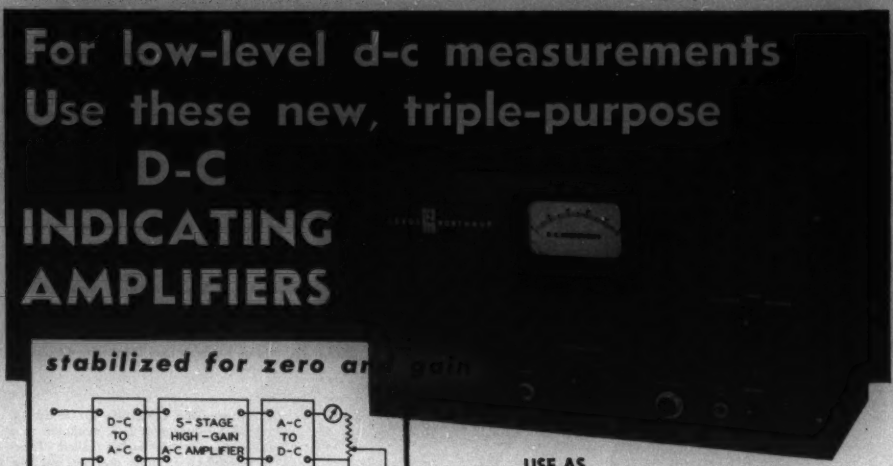
original can be copied, and all exposing and developing of the film is done within and by the machine. The Copyflex needs no installation—it can be placed anywhere and merely connected to the ordinary office electric light line carrying standard 60-cycle 110-volt alternating current. Additional information may be obtained from the Charles Bruning Company, Inc., 100 Reade Street, New York 13, N. Y., upon written request.

Vibrator Converters for Railroad Application. The Cornell-Dubilier Electric Corporation has introduced two new vibrator converters for railroad application. Both incorporate a self-servicing enroute feature, which is made possible by automatic switch-over to a stand-by vibrator when the service vibrator reaches the end of its useful life. Thus uninterrupted service is insured on the longest trip, with no attention required from the train crew. A warning light signal indicates need for vibrator replacement on routine maintenance check-ups. Model *3248* has been designed for a 32-volt d-c input and delivers 115-volt 60-cycle alternating current, with a maximum power output of 375 voltamperes. This unit is filtered for a broadcast band and is shock-mounted for passenger car service. Model *3212A* has been designed specifically for operating radio communications equipment in cabooses where 12 volts is the available source of power. It delivers 115-volt 60-cycle alternating current, with a power output of 175 voltamperes maximum. For complete technical data, write to the Cornell-Dubilier Electric Corporation, Indianapolis Division, 2900 Columbia Avenue, Indianapolis, Ind.

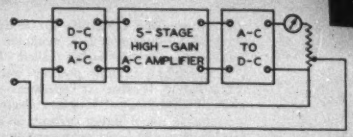
The Microsyn. A new type of regulating device—the microsyn—which provides regulation in infinitesimal steps, has been announced by the Westinghouse Electric Corporation, 306 Fourth Avenue, Pittsburgh 30, Pa. The basic idea for this instrument originated in the Instrumentation Laboratories of the Massachusetts Institute of Technology. The microsyn can do three kinds of things: it can produce a voltage proportional to turning a rotor over a range of ±10 degrees, with a sensitivity of 20 seconds; it can produce a torque that is linear with the square of a signal current; and it can act as an elastic restraint generator, producing a torque proportional to the product of the square of a current and the angular displacement. The microsyn consists of a moving element in a 4-pole field. The magnetic structure is of Hipernik, specially processed to give a hysteresis loop of small area and a permeability of 100,000 with 0.03 oersted coercive force. This specially processed Hipernik alloy has extremely consistent characteristics. In order to achieve consistent and precise results, the microsyn must have very accurate dimensional control—all ground surfaces must be accurate to 0.1 mil. Further details may be obtained from Westinghouse Electric Corporation.

(*Continued on page 32A*)

For low-level d-c measurements Use these new, triple-purpose D-C INDICATING AMPLIFIERS



stabilized for zero and gain



Voltage-balance feedback (above) and current-balance feedback stabilize gain . . . provide virtual null balance.

SPECIFICATIONS

MICROVOLT UNIT	MICRO-MICRO-AMPERE UNIT
Catalog No. 9835	Catalog No. 9836
FULL SCALE RANGES WITH BUILT-IN 4" METERS	
0 to 50 or —25 to +25 Microvolts; scale multipliers: 1,2,4,10, 20,40	0 to 1000 or —500 to +500 Micro-Micro-amps; scale multipliers: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000
ACCURACY	
Of amplifier: ±0.4% of reading ±0.5 Microvolt; Of meter: ±1%	Of amplifier: ±0.5 to 0.8%* of reading ±20 Micro-Micro-amps; Of meter; ±1%
STABILITY	
Zero and Gain stabilized automatically. No trimmer controls required.	
***SOURCE RESISTANCE**	
Up to 10,000 ohms.	0.1 megohm or more.
RESPONSE TIME	
2 to 3* sec.	2 to 3* sec.
OUTPUT	
For full scale input on any range: 10 millivolts at output impedance of 500 ohms for null recorder; 1 volt for 20,000-ohm external meter.	

Front panel fits standard 19" relay rack.

*Accuracy and Response Time depend on Source Resistance.

USE AS

- **DIRECT-READING MICROVOLTMETER OR MICRO-MICROAMMETER**
- **RECORDER PREAMPLIFIER**
- **NULL DETECTOR**

These new instruments are not only D-C Indicating Amplifiers but are stable, accurate measuring instruments as well. You can use them in measurements with thermocouples, strain gages, bolometers . . . bridge and potentiometer circuits . . . ionization, leakage, and phototube currents . . . almost any measurement of extremely small direct current or voltage.

Through a combination of a-c amplification and unique balanced feedback network, zero and gain stability are designed right into the instrument. Trimmer controls are designed out—eliminated.

Actually *three* instruments in one, these amplifiers can be used as—

Direct-reading instruments . . . At the turn of a scale-multiplier knob, you simply select the range in which you want to work.

Recorder preamplifiers . . . with broad flexibility. For instance, one or two degrees of temperature difference can be spread across an entire Speedomax recorder scale.

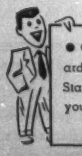
Null detectors . . . more sensitive than most reflecting galvanometers, yet with full scale response time of only 2 to 3 seconds. Leveling is unnecessary. There's no worry about shock or vibration. At the turn of a range knob, you have available a wide choice of sensitivities. External shunts are not required. And when using non-linear response, not only does the instrument stay on scale at extreme unbalance; sensitivity increases automatically as the null point is approached. For details, write to Leeds & Northrup Co., 4962 Stenton Ave., Phila. 44, Pa.

Jrl ad EM9-51(1)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES
LEEDS & NORTHRUP CO.

DESIGN — Engineers have found that time is saved by using Standard's design service whenever they specify transformers for use in special projects. Long design experience on transformers for all needs, including power, distribution, metering and testing, is at your service.

MANUFACTURING — Standard's methods are set up for quality production . . . many functions ordinarily left to mass methods are performed by specialists and skilled mechanics who do custom work. Specifications established by ASA are met or exceeded. Job proved products are your assurance of complete satisfaction.

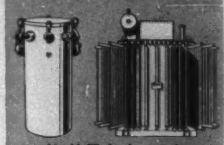


● Get acquainted with The Standard Transformer Company. Be sure Standard's booklet CL-50-EE is in your files.

OFFICES IN PRINCIPAL CITIES

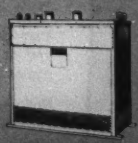
THE Standard TRADE MARK TRANSFORMER CO.
WARREN, OHIO
(Exclusively transformer designers and manufacturers)

TRANSFORMERS FOR EVERY APPLICATION



Liquid filled (sizes up to 10,000 KVA and 72 KV inc.)

Instrument transformers (for use on circuits up to 72,000 volts, inc.)



Dry type (up to 1000 KVA and max. voltage ratings of 4800)

Control transformers (compound filled or open type)

(*Continued from page 30A*)

Fogheds. A water fog-producing device developed for use in fixed piping systems for the fire protection of oil-filled electric transformers, switches, and so forth, has been introduced by Fog Nozzle International, a division of the Akron Brass Manufacturing Company, Inc., Wooster, Ohio. Because water fog is a nonconductor of electricity, the Fogheds may be installed relatively close to the hazard involved; therefore, the proper application of the water fog to the hazard under exposed conditions out-of-doors is assured. As transformer oils are of very high flash point and only the extreme temperature of an electric arc will cause vaporization of this oil, it follows that when this material is cooled below its vaporization point, the fire is extinguished. Additional information on Fogheds may be obtained from the company.

Nonconsumable Electrode for Welding. Thoriated tungsten is now available as a nonconsumable electrode (called Thor-Tung) for d-c straight polarity welding. Thor-Tung, because it operates much cooler than standard tungsten electrodes, permits the use of higher currents on given size electrodes and does not become molten, so that consumption is negligible and contamination resulting from accidental or deliberate touching is eliminated. Thor-Tung may also be pointed to permit continued operation at very low current. Further details are available from Air Reduction, 60 East 42nd Street, New York 17, N. Y.

Thyratron Tube. A new gas thyratron tube which can operate at maximum ratings over a wide temperature range has been announced by the General Electric Tube Divisions. The new tube, designed mainly for general control-circuit applications, has a quick-heating cathode which takes only a minute to reach operating temperature. Designated the *GL-5855*, the 3-electrode inert-gas-filled thyratron has a commutation factor rating of 200. Thus it can be used in motor control without the need for snubber circuits and without the occurrence of gas clean-up. (Commutation factor is the product of the rate of current decay in amperes-per-microsecond just prior to commutation and the rate of inverse voltage rise in volts per microsecond just after commutation.) Maximum ratings include: maximum peak anode voltage, 1,500 volts; maximum cathode current, peak 150 amperes, average, 12.5 amperes; maximum negative control-grid voltage, 250 volts before conduction and ten volts during conduction. Further information on the *GL-5855* may be obtained from the Tube Division, General Electric Company, Schenectady, N. Y.

Inputuner. The new Du Mont series *T3A* inputuner provides reception of frequency modulation as well as television channels by employing the Mallory-Ware

(*Continued on page 38A*)

ROCKBESTOS A.V.C.® CARRIES 32% GREATER LOAD

YET BOTH ARE THE SAME SIZE

Compare A.V.C. with Type RH in a 250 MCM size*

- you use 2½" conduit for both
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For more efficient current-carrying capacity, always specify Rockbestos A.V.C. Write for the booklet "Cut Current Carrying Costs."

*From Chapter X—National Electrical Code—3 conductors in conduit—40°C-104°F.

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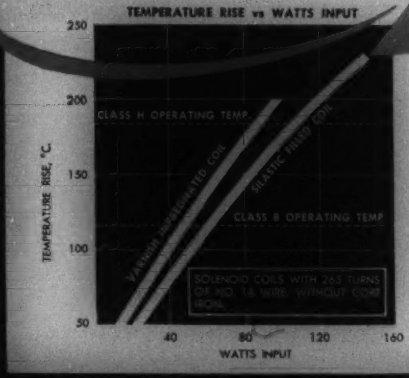
SILASTIC* the resilient dielectric, stable from -60° to +200°C.



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Thermal stability plus high heat conductivity permit the Silastic coil to operate at 166% of the maximum capacity for an identical organic resin impregnated solenoid. Performance of over 1600 Silastic insulated main and interpole field coils in diesel-electric traction motors is further proof of the extraordinary advantages of Silastic as a dielectric.

In coils of all kinds, Silastic provides resiliency and relatively constant dielectric properties of temperatures ranging from below −60° to above 200°C., maximum resistance to corona, to electrical and mechanical fatigue and to abrasion, oil and outdoor weathering.

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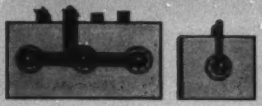

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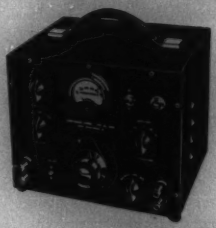

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Resistors from 10 ohms up to 1 megohm are measured by the comparison method at 60 cycles. Resistors of greater value than 1 megohm can be measured by using the instrument as a limit bridge. Condensers from 500 micromicrofarads up to 10 microfarads are measured by the comparison method at 1000 cycles. Condensers above 10 microfards are measured by the comparison method at 60 cycles. Small condensers 500 micromicrofarads to 25 micromicrofarads are measured at 1000 cycles, with the instrument used as a limit bridge. Inductors can be measured at 60 cycles, 1000 cycles or 10,000 cycles, depending upon their values.

Ranges:				
L—100 Hy to 1 Hy	F— 60 cycles
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A series of four articles, compilations of papers originally presented at a symposium on electrical properties of semiconductors and the transistor, held during the AIEE Summer General Meeting, Swampscott, Mass., June 1949. Sponsored by the Subcommittee on Electrical Properties of Solids and Liquids of the AIEE Committee on Basic Sciences.

It is hoped that this pamphlet (S-36, January 1950) will prove useful not only to the practicing engineer and teacher, but also to engineering students as an introduction to this field of electrical engineering.

Price is $0.50 ($0.25 to AIEE members). Send orders to: Order Department, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 39th Street, New York 18, N. Y.

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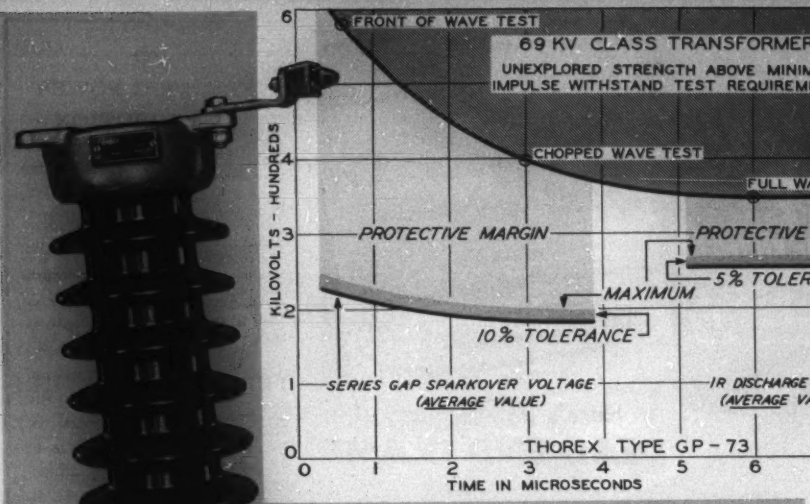

Lets look at LIGHTNING ARRESTER TOLERANCE another way..

- **You add it to average ratings**
- **But take it from Protective Margins**
- **Can you afford to waste any arrester protection?**

The story of lightning arrester tolerance is told in graphic terms in the accompanying curves relating to a typical 69-kv transformer. All published arrester values are *average* ratings to which tolerance is *added*. Between these basic *average* ratings and the demonstrated strength of the transformer exists a zone called the "Protective Margin". It's not so important that tolerance is added to published values as it is that tolerance is *deducted* from that vital Protective Margin. This is just a different way of saying the same thing--but an important difference!

--And while you are considering tolerance, bear in mind that the O-B Thorex arrester has by far the closest tolerance ratings offered on the American market; giving you wider, more usable Protective Margins. Investigate this phase of the O-B Thorex.

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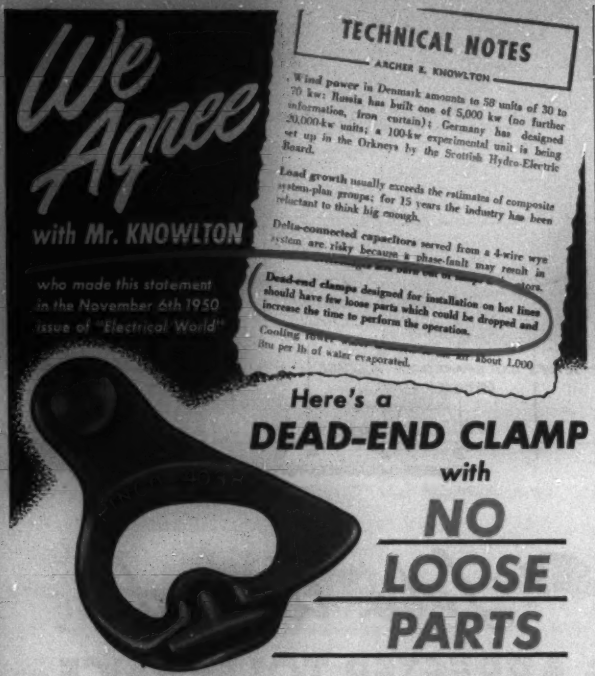
We Agree
with Mr. KNOWLTON
who made this statement in the November 6th 1950 issue of "Electrical World"
TECHNICAL NOTES
ARCHER E. KNOWLTON
Wind power in Denmark amounts to 50 units of 30 to 70 kw; Russia has built one of 5,000 kw (no further information, from curtain); Germany has designed 20,000-kw units; a 100-kw experimental unit is being set up in the Orkneys by the Scottish Hydro-Electric Board.
Load growth usually exceeds the estimates of composite system-plan groups; for 15 years the industry has been reluctant to think big enough.
Delta-connected capacitors served from a 4-wire wye system are risky because a phase-fault may result in
Dead-end clamps designed for installation on hot lines should have few loose parts which could be dropped and increase the time to perform the operation.
Cooling
Btu per lb of water evaporated.
about 1,000
Here's a
DEAD-END CLAMP
with
NO
LOOSE
PARTS

If this is news to you, then it is our fault—because this Pinco L 4038 Dead-End Clamp was introduced eleven years ago! Prior to that time, all other clamps of this type had as many as *eight loose parts* which made them extremely difficult to assemble on the job.

The Pinco L 4038 Clamp with its simplified design not only speeds up installation but shows definite improved vibration characteristics with small copperweld or stranded copper conductors—(from .16" to .375" diameter inclusive). Today's model is even more efficient. An *extra long* J-Bolt Keeper of improved design *doubles* the clamping area on the conductor (contacts *all* wires in the long-lay conductors) . . . holds them securely without damage.

This Pinco L 4038 Clamp is another example of sound product planning which pays off in improved performance. Remember this whenever you specify and buy insulators and line hardware.

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(*Continued from page 32A*)

3-section spiral inductuner plus antenna tuning. It is designed to work into the intermediate-frequency system of television receivers using a separate sound intermediate frequency, and is available with variations in the mixer-plate network, making it adaptable without alteration to various types of separate sound intermediate-frequency receivers. Input impedance is 300 ohms. Inclusion of the sound trap with the tuner is optional as well as the choice of either 21.25 or 21.75 megacycles per second sound center intermediate frequency. The tuner comes complete with a *6BC5* radio-frequency tube and a *6J6* mixer-oscillator. Any further details may be obtained from Allen B. Du Mont Laboratories, Inc., 35 Market Street, East Paterson, N. J.

TRADE LITERATURE

Loss Prevention Bulletin. "Properties of Flammable Liquids, Gases, and Solids," bulletin number *36.10*, is a source book for fire prevention engineers, published by the Factory Mutual Engineering Division, 184 High Street, Boston 10, Mass. It is available upon request.

Characteristics of Television and Cathode-Ray Tubes. A new booklet, "Sylvania Television Picture Tubes and General Purpose Cathode Ray Tubes," contains characteristics of 194 cathode-ray tubes for television receivers, oscilloscope and radar applications. It is available from the Advertising Department, Sylvania Electric Products, Inc., Emporium, Pa.

Measuring Dynamic Pressures. A newly developed measuring system for directly obtaining true dynamic pressure variations is described in a folder published by Electronic Associates, Ltd., 778G El Camino Real, San Carlos, Calif. Identified as form *SA5-950*, this publication contains a discussion of the problems involved in correcting conventional measurements for phase and amplitude errors inherent in tubing-connected pressure-sensing cells. Copies are available from the company.

Electronic Tube Engineering Manual. An engineering manual and catalog which covers the subject of gaseous discharge-rectifier and control-rectifier tubes, tube protection, efficiency, regulation, mechanical design and variations, has been issued by Electrons, Inc., 127 Sussex Avenue, Newark 4, N. J. It may be obtained from the company upon request.

Locknuts. "Types of Locknuts" and their principles of operation are illustrated and discussed in a new booklet which is available from the Locknut Section, Industrial Fasteners Institute, 3648 Euclid Avenue, Cleveland, Ohio.

Magnetic Amplifier Service Sheets. The Vickers Electric Division, Vickers, Inc., 1815 Locust Street, St. Louis 3, Mo., has issued a new set of service sheets for their

(*Continued on page 46A*)

This winding-insulation tester is used to surge test all semi-open-slot stators turned out in this plant.

WINDING-INSULATION TESTER

for Faster and Better Motor Testing

One motor manufacturer recently told us that since installing a General Electric Winding-Insulation Tester he has—

- **cut rejects on motors from 4% to 0.1%**
- **been able to test as many as 10 stators a minute in the small sizes**
- **been able to find faults that other tests would not show.**

The G-E Winding-Insulation Tester is also applicable for testing generators, transformers and coils. With it you can:

- **conduct over-all surge tests**
- **detect too many or too few turns**
- **detect grounds, short circuits, open circuits, shorts between turns and shorts between phases.**

Call your G-E sales office or see your authorized G-E distributor soon. For free descriptive literature **CLIP THE COUPON**

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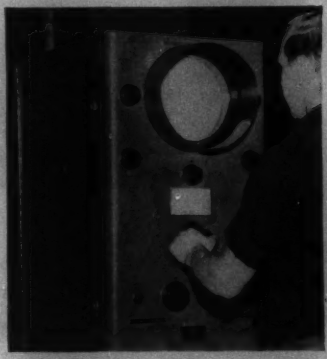

The test operator easily detects faults by observing the wave shape on the scope. Variations in the oscillogram indicate the nature of the fault if any.

Section A687-61, Apparatus Dept.,
General Electric Co., Schenectady, New York

Please send me bulletin GEC-321 on your winding-insulation tester.

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Position.....

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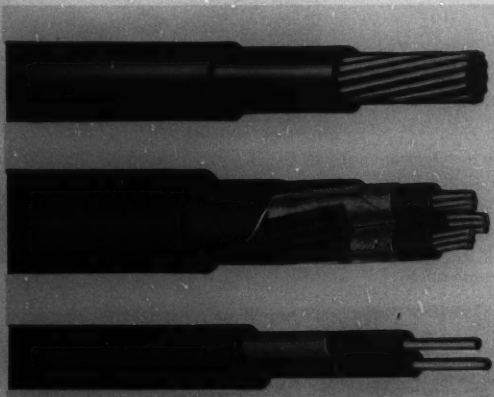

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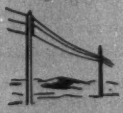

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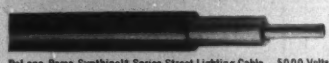

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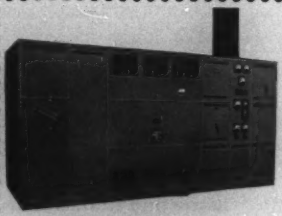

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1000 KVA, 4160Y 60 Cycles, 3 Ø —480 delta; Fused, load interrupter on H.V. (left). Drawout type breakers and metering equipment on L.V.

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AIEE REPORTS

These publications are proposals for new standards or test codes, or revisions of present publications, which are in the formative stage.

They are made available, without cost, so that all interested individuals may obtain them for study and comment, thereby supplying practical experience in their use before submission for adoption.

20A Low-Voltage Air Circuit Breakers (December 1946)

22A Air Switches, Insulator Units, and Bus Supports (October 1949)

24 Protector Tubes (July 1940)

28A Valve and Expulsion Type Lightning Arresters (February 1950)

50 Automatic Circuit Reclosers for A-C Distribution Systems (September 1949)

51 Guiding Principles for Dielectric Tests (September 1949)

502 Test Code for Single-Phase Motors (November 1941)

800 Test Code for D-C Aircraft Machines (March 1947)

801 Test Code for Aircraft Interrupting Devices (August 1950)

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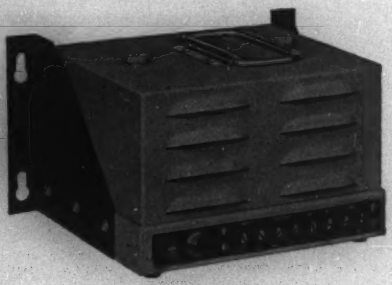
WESTON Inductronic* D-C AMPLIFIER

with Sensitivity and Stability



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"Hot spots" and resultant failures are prevented by the resistance winding's unsurpassed uniformity.

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Unaffected by cold, heat, fumes, or high humidity, its core provides a strong base for winding.

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Lengths range from 1¼ inch to 6 inches, corresponding to ratings of 30 to 75 watts.

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Distribute heat more evenly throughout resistor and conduct heat away quickly.

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Because of their compact design, Ohmite Thin Type Resistors have a higher wattage rating per unit of space. They provide all the time-proven superiority of conventional Ohmite vitreous-enamel resistors—giving you a compact unit you can depend upon. Available in four types—all only ¼ inch thick by ½ inch wide—in five lengths and a wide range of resistance values.

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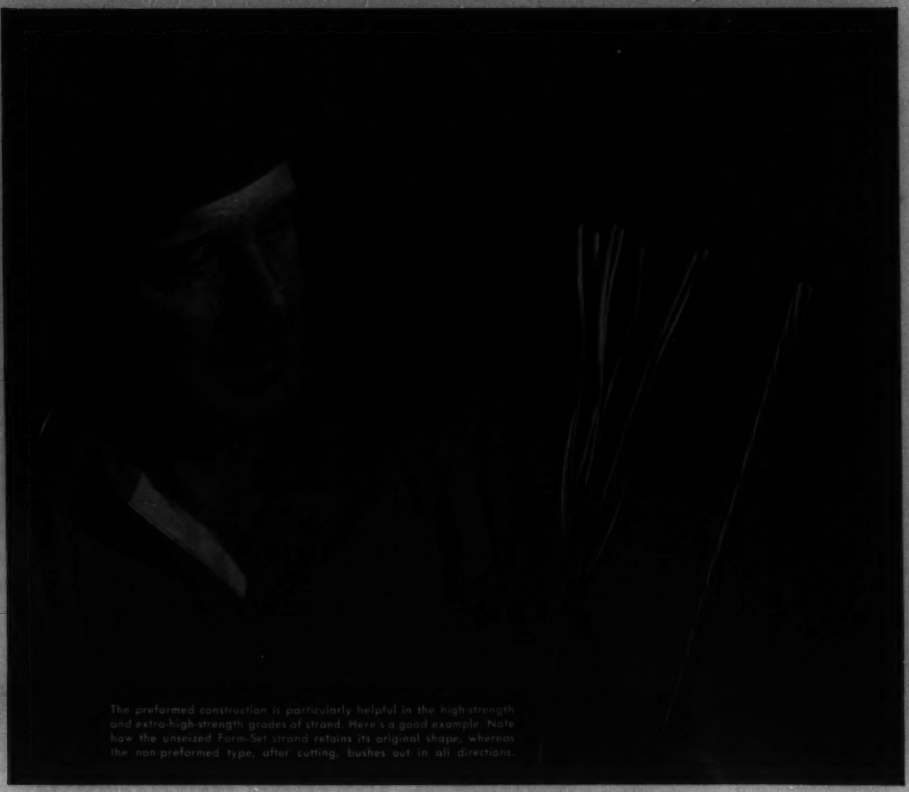

The preformed construction is particularly helpful in the high-strength and extra-high-strength grades of strand. Here's a good example. Note how the unseized Form-Set strand retains its original shape, whereas the non-preformed type, after cutting, bushes out in all directions.

Why FORM-SET Strand is EASIER to handle

The basic reason, of course, is that Bethlehem Form-Set strand is *preformed* strand; the wires, one by one, are relieved of internal tension before being laid together. This is accomplished by giving each wire its permanent curl or shape before it goes into the strand with its neighbors.

Form-Set's reduced wire tension means several practical advantages. The strand doesn't "explode" when cut . . . it need not even be seized. Hence it slides quickly, smoothly, into the ends of fittings; there's no lost time, no pinching together of stubborn wires. Matter of fact, in Form-Set, there isn't any stubbornness at all.

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Order a reel of Form-Set; have your linemen try it. Then, just as a check, ask them how they like this strand. We think they'll confirm what we've told you.

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There are 12 items in the XL line. Insert arrangements available: 3—15 amp. contacts, 4—10 amp. contacts—working voltage 250 volts. Zinc and steel plugs with bright nickel finish are standard. Satin chrome finish also available on steel plugs.

(*Continued from page 38A*)

DH-2 handbook, containing a classification chart, *2600*, and bulletins *2201-08*; *2211-18*. These new service sheets may be obtained from the company upon request.

The Control Story. "The Control Story" briefly outlines types and applications of automatic controls in heating, ventilating, and air-conditioning systems for the architect and engineer who specify this equipment. Copies are available from the Barber-Colman Company, Rockford, Ill.

Motion Picture Camera Bulletin. The Flight Research Engineering Corporation, Post Office Box 1-F, Richmond 1, Va., has published a bulletin describing their new model IV 35-millimeter synchronous motion-picture camera. The bulletin is available from the company upon request.

Phono Accessories; Educational Equipment for Labs. The General Electric Company has made available two new booklets: a phono accessory catalog containing technical data on their variable reluctance cartridges, replacement baton styli, tone arms, and phono preamplifiers; and a 16-page bulletin on educational equipment for electrical laboratories. Designated as publication *GEA-5526*, this bulletin deals with rotating apparatus, loading devices, instruments, motor control equipment, distribution equipment, and dynamometers. The former bulletin is available from the Electronics Department, General Electric Company, Syracuse, N. Y., and the latter bulletin, *GEA-5526*, may be obtained from the company at Schenectady 5, N. Y.

Coil Spring Buyer's Guide. Intended primarily for the use of purchasing agents and coil spring buyers, the "Spring Buyer's Guide" published by the Hunter Spring Co., Lansdale, Pa., also is valuable to engineers and others who deal with springs, because it discusses the various factors affecting the cost of these springs. It is available upon request.

"The Tool for the Job." The Air Reduction Sales Company has completed a Kodachrome sound motion picture, which tells the story of the new Aircomatic process for welding aluminum, stainless steel, bronzes, and monel. Showing time for this 16-millimeter, 2-reel picture is 21 minutes. It was designed for showings to engineering meetings and technical society groups. For further details, and to make arrangements for the showing of "The Tool for the Job," contact Air Reduction, 60 East 42nd Street, New York 17, N. Y.

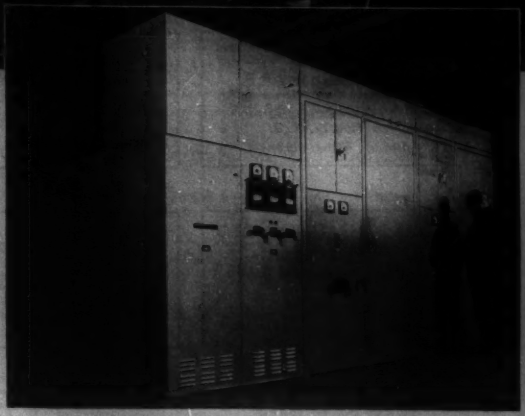
Wood and Fibre Wedge Information. The latest data on both wood and fibre wedges, which are used to hold windings in motor slots, reduce mechanical hum in transformers, and for other electrical purposes, has been made available by the Insulation Manufacturers Corporation, 565 West Washington Boulevard, Chicago 6, Ill.

Cohoes, N. Y. protects pumping plant equipment

with G-E Limitamp high-voltage control

Recently, Cohoes installed a new 500-horsepower G-E synchronous motor on a raw water pump. Before they selected control the city engineers wisely decided on a complete study of the power supply. Working with the G-E sales engineer they determined the available short circuit capacity of the system was 60,000 kva. The destructive potentialities of this power obviously called for an "insurance" that would protect their investment.

G-E Limitamp was the "insurance". It answered every need. In addition to controlling the motor, its co-ordinated design, using current-limiting EJ-2 fuses, will clear shorts in less than half a cycle—well before damage can occur to motor or control. Extra dividends in the new smaller size, protection to personnel, reduced installation, engineering, and maintenance costs are inherent in this equipment, too.



G-E Limitamp installed at Cohoes, N. Y. for control of two 500-horsepower motors

For your high-voltage installation ask for G-E Limitamp—now available in ratings up to 4800 volts with an interrupting capacity up to 250 kva. Protect your power system and motors with G-E Limitamp—more information in Bulletin GEA-5409. Ask the nearest G-E office for this bulletin or write Section 730-23, *Apparatus Dept., General Electric Company, Schenectady, N. Y.*

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Joint AIEE-NTF Conference on Telemetering

AIEE Special Publication S-41 contains papers and discussions presented at the technical conference on telemetering sponsored by the American Institute of Electrical Engineers and the National Telemetering Forum (NTF) held in May 1950.

Five general sessions were given. The first session is devoted to the general features of telemetering, its functional classifications, and the historical backgrounds of the AIEE Joint Subcommittee on Telemetering and Supervisory Control, the AIEE Committee on Instruments and Measurements, and the NTF, in order to establish a common language between both groups. The remaining sessions emphasize the technical aspects of the subject—telemetering systems, telemetering systems and pickups, and other related telemetering topics—to complete the general telemetering picture.

Orders for publication S-41 should be sent to:

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PHYSICIST, GS-11. Supervisor of a radar unit, in the Aviation Ordnance Department, to supervise the design and development of components of radar systems. Requirements: B.S. degree in physics; four or more years experience in electricity and magnetism research; and a thorough knowledge of mathematics through advanced calculus and differential equations. Salary: $5,400.

PHYSICIST, GS-11. To do experimental work in connection with the development of an analogue computer for aircraft fire-control systems in the Aviation Ordnance Department, Systems Development Division. Requirements: Applicants should have considerable research, study, or experience in the computer field. Salary: $5,400.

ELECTRONIC ENGINEER, GS-11. To do development and testing on countermeasure projects on the staff of the Test Department. Requirements: Engineering or development experience in the field of microwaves and high-frequency pulse techniques; ability to write reports, specifications. Salary: $5,400.

ELECTRONIC ENGINEER, GS-11. Project leader of Aviation Ordnance, Special Controls Division, to work on the application of new theories in the field of automatic control and instrumentation. Requirements: Extensive knowledge of past and current developments in servomechanisms. Salary: $5,400.

ELECTRONIC ENGINEER, GS-12. Head of the Radar Section, Metric Electronics Branch, Instrument Operations, Test Department, who will be responsible for all aspects of radar operation on the ballistic ground ranges, and will work on the design and development of electronic equipment. Requirements: A thorough background in radar. Salary: $6,400.

ELECTRONIC ENGINEER, GS-11. To work on the development and testing of electromechanical components of fire-control systems, in the Aviation Ordnance Section, Aircraft Fire Control. Requirements: B.S. degree or equivalent in electrical or mechanical engineering and experience in recent electronic theories and applications. Salary: $5,400.

ELECTRONIC ENGINEER, GS-11. To supervise a Radar Field Unit, and work on the design and development of electronic equipment, in the Metric Electronics Section, Instrument Operations. Requirements: A thorough background in radar. Salary: $5,400.

ELECTRONIC ENGINEER, GS-11. Group leader for research, design, development, and operation of electronic devices for use in telemetering, doppler, magnetic pickups, and guided missiles. Requirements: Several years of research, lab, and government experience in these fields. Salary: $5,400.

TRAINING SPECIALIST, GS-12. Head of the Training Division, Personnel Department, to assume full responsibility for apprentice, junior professional, and summer training programs for undergraduate and graduate students, management training for top level supervision, executive development program, and administrative responsibility for operations of the Division. Requirements: Appropriate professional degree plus at least four years in technical training work or education. Salary: $6,400.

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ELECTRICAL ENGINEER, having several years' experience in the design and construction of major hydro-electric plants, for employment in Seattle office. Prefer man not over 50 years of age and must be U.S. citizen. Address: Seattle City Light, 1015 3rd Avenue, Seattle 4, Washington.

ELECTRICAL ENGINEER—Nationally known trade journal needs man with power generation and electric utility experience for assistant editor. Age 28–35. Submit complete résumé, stating salary desired. Address Box EE 1049, 221 W 41st Street, New York, N. Y.

ELECTRONIC ENGINEER, instrument development, Test Department, to act as task supervisor of specialized radar problems in a scientific research program. Includes coordination of the effort of several scientific task groups in varied phases of electronic test and development work. Rating: GS-11; salary $5,400. Requirements: Several years' experience above B.S. degree in the technical field, as well as ability to evaluate and direct a scientific test and development program. Write for full information and application forms to: J. B. Hamilton, Professional Placement Branch, Naval Ordnance Test Station, Inyokern, China Lake, Calif.

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ELECTRONIC SCIENTIST, to act as Senior Project Engineer on the staff of the Test Department, to develop and test countermeasure projects. Rating: GS-12; salary $6,400. Requirements: Engineering or development experience in microwave and high-frequency pulse techniques; ability to write reports, specifications. Write for full information and applications forms to: J. B. Hamilton, Professional Placement Branch, Naval Ordnance Test Station, Inyokern, China Lake, Calif.

NOTE: Closing date for material to be set in the classified advertising column, as well as cancellations for running ads, must be received not later than the first of the month preceding issue; i.e., July first for August issue.

EDITOR, Aviation Ordnance Department, to edit and write reports of technical studies, tests and projects in the engineering and physical science fields and to supervise other editorial personnel and illustrators. Rating: GS-11; salary $5,400. Requirements: A technical background, consisting of at least a B.S. degree, and extensive experience in engineering or scientific fields, and at least three years' experience in technical writing and editing. For full information and application forms write to J. B. Hamilton, Professional Placement Branch, Naval Ordnance Test Station, Inyokern, China Lake, Calif.

ELECTRONIC ENGINEERS. One to four years' professional experience in the design, development, modification, construction, and testing of electronic equipment such as radar, radio, wire communications equipment, electronic control and measurement instruments, and sonar equipment. Salary: $3,825 to $6,400. Applicants should write or apply in person to the Civilian Personnel Branch, Building T-530, Fort Monmouth, N. J. If possible, a completed standard form 57, application for federal employment, which can be obtained at any post office, should be submitted at time of interview.

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ELECTRICAL ENGINEER, Age 26, Single. BSEE, MSEE, two years Ch.E. study; Navy aviation electronics training; one year management training program in industry, one year university instructor in electronics, one year electronics field engineer. Desire position involving travel and individual contact work. Locate anywhere. Address: Box 102, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL ENGINEER, Age 37, MS in EE. Aircraft power generation AC and DC, advanced high speed high altitude machines, sonic and supersonic cooling problems, magnetic power amplifiers, missiles, research work. Excellent theoretica. background. Also commercial electrical machinery. Graduate Professor. 10 years experience. Desire administrative or executive position. Address: Box 103, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL ENGINEER, BSEE, age 33, desires position as chief engineer in small progressive organization manufacturing small electromechanical devices, semiconductor elements, or instruments. Experience with large electrical manufacturer for 10 years. Considerable technical training since graduation in metallurgy, electronics, nuclear physics, and also business training. Registered professional engineer. Address: Box 104, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

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Apply by letter addressed to the key number, and mail to New York Office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription rate of $3.50 per quarter or $12 per annum, payable in advance.

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GENERAL MANAGER, electrical graduate, with five to ten years' experience in radio or television manufacturing. Salary, $20,000-$25,000 a year. Location, New York, N. Y. Y-4627.

DESIGN ENGINEER, electrical graduate, with at least ten years' utility or large industrial power plant supervisory design experience, to take full responsibility for design, layout, specifications, etc., for consulting firm. Salary, $8000-$10,000 a year. Location, New York, N. Y. Y-4646.

SALES ENGINEERS, 2, electrical, 26-30, with electronic equipment experience, to sell potentiometers, X-ray testing, photo engraving and electronic components. Considerable traveling. Territories, Midwest and California. Headquarters, Ohio. Y-4661.

RESEARCH ENGINEERS, physics, electrical or mechanical engineering graduates, with minimum of three years' experience in development of electronic equipment, thermodynamic equipment, and in the final engineering of electronic and thermodynamic equipment. Opportunities for creative work and project supervision on micro-wave relay equipment, communications equipment, vacuum tubes and semiconductors, television, radar, radio and special devices. Salary open. Location, Pennsylvania. Y-4681.

PROFESSOR AND HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING, young, with at least an M.S. in E.E., but a Doctor's degree preferred. Should have experience in both teaching and industry. Should be interested in developing a teaching department as well as research in electronics, communications and power. Location, West. Y-4692.

ELECTRICAL ENGINEERS, 2. Must have electrical engineering degrees. One for office engineering on design, layout and estimating of power and lighting. Salary, $6500-$7200 a year. One for inspection of all electrical power and lighting equipment. Salary, $5200-$5500 a year. Location, New York, N. Y. Y-4715.

SUPERVISOR, electrical graduate, with seven to ten years' in design and development engineering, with one or two years' in a supervisory capacity. Thorough knowledge of design and development of electrical and electronic equipment and testing equipment. Will supervise and direct all activities performed by engineers and technicians, design and check performance of electrical and electronic equipment, testing instruments and other complicated electrical devices. Analyze existing patents, schedule engineering projects, control rate of expenditures, supervise pilot model performance tests, edit all manuscripts, and report to and confer with the chief engineer. Location, Connecticut. Y-4745.

ELECTRICAL ENGINEER, graduate, with four to seven years' experience, with knowledge of electrical engineering design and development of new electrical devices of a complicated nature. Will design electrical components such as stable and linear Class A and DC amplifiers, pulsers and I.F. amplifiers; prepare cost estimates and material specifications for a given project. Collect all necessary data and make calculations for assigned projects; check sources and availability of materials required. Will be responsible for layout and detailed drawings required; check performance of pilot models; render progress reports and prepare patent disclosures. Location, Connecticut. Y-4746.

SUPERVISOR, research, electrical engineering degree, plus one or two years graduate work in electronics, equivalent to a Master's degree. Seven to ten years' experience in design, development and research engineering. Thorough knowledge of research and experimental methods, etc., in electronics and physics. Will supervise and direct engineers and technicians engaged in carrying out research and development projects. Render complete final reports, conduct research projects, prepare patent disclosures, consult with mechanical and electrical engineering supervisor on research problems, etc. Location, Connecticut. Y-4747.

DEVELOPMENT ENGINEER, electrical graduate, with five to eight years experience in the research and development of electrical test and instrument equipment. Salary, $6000 a year and up. Location, northern New Jersey. Y-4626(x).

ELECTRICAL ENGINEER, particularly well versed in electrical design of distribution transformers and a sound knowledge of mechanical design and general knowledge of manufacturing methods. Capable of assuming the direction of several electrical and mechanical designers in the development of distribution transformers. Will serve as assistant to the chief engineer. Salary, $5000-$6000 a year. Location, Milwaukee, Wisconsin. R-7042.

ELECTRONIC DEVELOPMENT ENGINEER, with about three years' experience required on the development and design of hearing aids, miniaturigations and circuits. Knowledge of audio amplification. Duties: research, design and development of electronic hearing aids. Supervisory position. Salary, $6000-$8400 a year. Location, Chicago, Illinois. R-7096.

DESIGN, DEVELOPMENT, APPLICATION, RESEARCH ENGINEERS OR PHYSICISTS in the field of electronics, mechanics or administration as encountered in complete guided missiles operation. Will consider applicants from recent graduates to Ph.D. Clearance for work on classified projects required. Salaries, up to $12,000 a year. Southwestern United States. R-7200.

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Send complete résumé (Listing salary requirements and availability) to: TECHNICAL PERSONNEL, ELECTRONICS PARK, SYRACUSE, N. Y.

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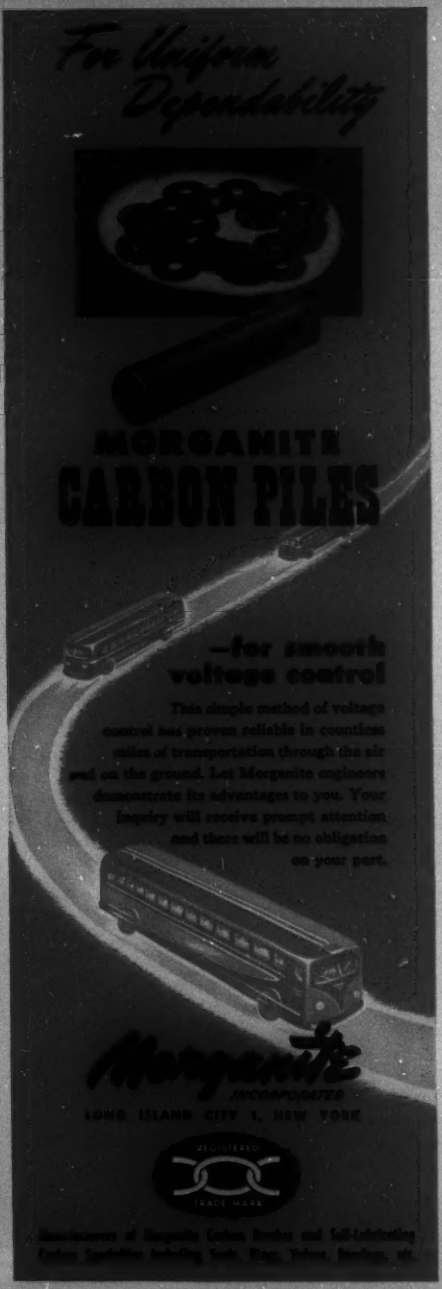
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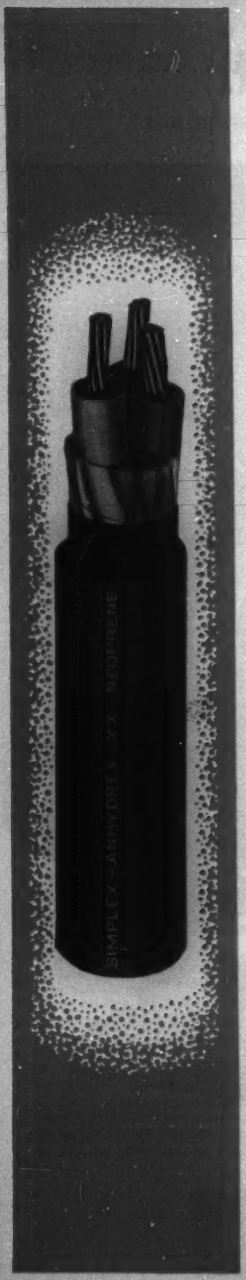

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For the first time these three important properties, moisture resistance, ozone resistance, and resistance to heat and aging, are combined in a single high-voltage insulation. Simplex-Anhydrex XX insulation has proved itself to be far and away your most dependable assurance of low cost, trouble-free cable operation at the higher voltages. Here's why:

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Cole Electric Co.

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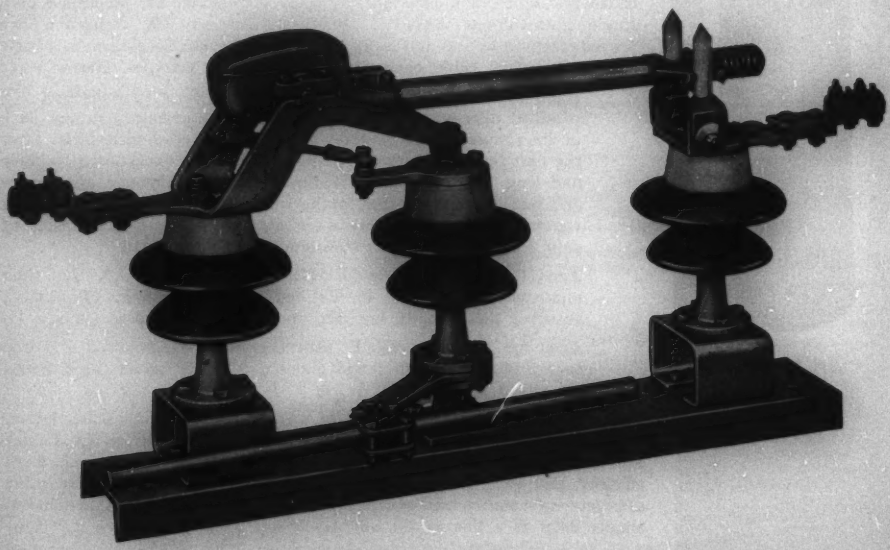
Tests made in our laboratory under severe icing conditions show the switch illustrated below, closed (left) and after opening (right). Ice was over 1" thick. Only 4.50 inch pounds were required to open switch.



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Vertical Break, Three Pole, Single Throw, Group Operated
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Type 736-A WAVE ANALYZER $1075

Specifications

★ **FREQUENCY RANGE:** 20 to 16,000 cycles.
★ **SELECTIVITY:** About 4 cycles flat-top band width. Response is down 15 db at 5 cycles, 30 db at 10 cycles, 60 db at 30 cycles from peak.
★ **VOLTAGE RANGE:** 300 microvolts to 300 volts full scale. Over-all range is divided into four major ranges, each of which is divided into seven scale ranges.
★ **VOLTAGE ACCURACY:** Within ± 5% on all ranges.
★ **HUM:** Suppressed by at least 75 db.
★ **INPUT IMPEDANCE:** 1 meg ohm for direct voltage measurements; 100,000 ohms with input potentiometer.
★ **ACCURACY OF FREQUENCY CALIBRATION:** ± (2% + 1 cycle).
★ **BUILT-IN CALIBRATORS:** For both voltage and frequency.

This analyzer offers the simplest, most accurate and most direct method of measuring the amplitude and frequency of the components of any complex electrical waveform.

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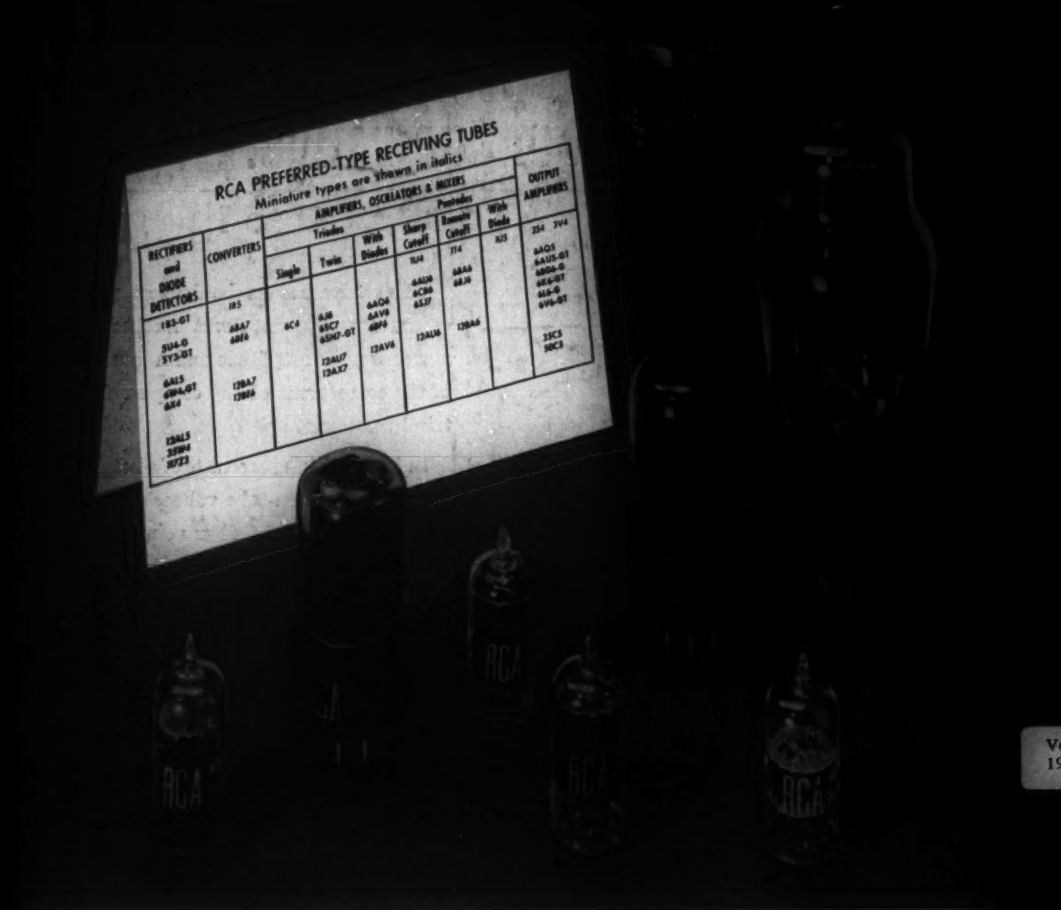

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